

INSTRUCTION MANUAL



RF400/RF410/RF415 Spread Spectrum Data Radio/Modem

Revision: 3/05

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– CAUTION –

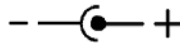
Where an AC adapter is used, CSI recommends Item # 15966. This AC adapter is included as part of Item # 14220 RF400 Series Base Station Cable/Power Kit.

Any other AC adapter used must have a DC output not exceeding 16.5 Volts measured without a load to avoid damage to the RF400 Series radio!

Over-voltage damage is not covered by factory warranty!

(See Power Supplies, Section 4.2 for AC adapter requirements)

Power plug polarity



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RF400 Series Spread Spectrum Data Radio/Modems

1. Introduction

This manual covers the RF400 series radios — the RF400, RF410, and RF415. These radios differ from one another primarily in the radio frequencies at which they communicate. In this manual the term “RF400” can refer to the “RF400 series” or to that specific model. For clarity we will sometimes add “900 MHz.”

The RF400 is a 900 MHz, frequency hopping, spread spectrum, data radio/modem for point-to-point and point-to-multipoint communications. An excellent receiver combined with 100 mW transmitter power make possible, depending on path specifics, communication distances of 1/4 to 5 miles using omni-directional antennas and 10 to 20 miles using 9 dBd directional antennas (see Appendix H for a discussion of antenna gain and other factors affecting distance).

The RF410 differs from the RF400 in that it operates at 922 MHz for regions such as Australia, New Zealand, and Israel. The RF410’s communication range is the same as that of the RF400.

The RF415 is a 2.4 GHz version with 50 mW transmitter intended mainly for certain European and Asian markets. Communication distances vary from 300 feet (indoors) to ¼ mile (100 to 400 meters) with omni-directional antennas to over 12 miles (19 kilometers) with gain antennas and optimal terrain.

Users do not normally need a communications authority license for the RF400 series configurations described in this manual including U.S. Government Agencies regulated by NTIA Annex K. The 900 MHz and 2.4 GHz bands are shared with other non-licensed services such as cordless telephones and with licensed services including emergency, broadcast, and air-traffic control, so band usage will vary from location to location as will man-made noise. Spread spectrum technology resists noise and interference; however, the user may wish to test communications on site using Quick Start (Section 3) before committing to its use.

The RF400 operates from a 12 VDC power supply. The RF400’s low standby current modes allow it to operate at remote sites on small power budgets.

The RF400 was designed for ease of installation. It works in many applications “out of the box” with default settings.



FIGURE 1. RF400

The RF400 has a 9-pin serial CS I/O port and a 9-pin serial DCE RS-232 port. The CS I/O port allows the RF400 to connect to a datalogger. The RS-232 port allows direct PC connection for Setup Menu access and to create a direct connect RF400 “base station” for point-to-point and point-to-multipoint communications. Where necessary, a more distant base station can be set up using short-haul modems or phone modems between PC and RF400.

Base Station power is usually provided by a wall adapter. For a remote RF400, power is normally provided by the datalogger.

A PC running LoggerNet, PC208W, or PC208 is used for data collection, program transfer, and other datalogger supported functions. The PakOS software or a terminal program is used to configure the RF400 radios.

2. RF400 Series Specifications

POWER

- Voltage 9 – 18 VDC
- Current 75 mA typical during transmit
24 mA typical receiving a signal
(36 mA for RF415)

Quiescent Current in Standby Modes*			
Avg. Quiescent Current (mA)		Advanced Setup Standby Mode	Standard Setup
RF400/ RF410	RF415		
24.0	33.0	0 (no duty cycling)	1
3.9	5.5	3	2
2.0	2.8	4	3
1.1	1.5	5	
0.64	0.84	6	
0.40	0.50	7	4

* Not receiving a signal nor transmitting

PHYSICAL

- Size 4.75 x 2.75 x 1.3 inches (12.1 x 7.0 x 3.3 cm)
- Weight 0.5 lbs (225 g)
- Operating temp. range -25°C to +50°C
- Humidity 0 to 95% RH, non-condensing

RF/INTERFACE

- Transceiver modules MaxStream
RF400 – 9XStream XO9-009
RF410 – 9XStream XH9-009
RF415 – 24XStream X24-009
- Frequency bands RF400 – 910.5 to 917.7 MHz
RF410 – 920.0 to 927.2 MHz
RF415 – 2.45015 to 2.45975 GHz
- Interface ports 1) CS I/O 9 pin
2) RS-232 9-pin (4 wire: Tx, Rx, CTS, GND)
- I/O Data Rates 38.4 K, 19.2 K, 9600, 4800, 1200 bps
- Mode Frequency hopping spread spectrum (FHSS), 25 hop channels, 7 hopping sequences, direct FM frequency control
- Channel capacity 65,535 addresses
- Transmitter output 100 mW nominal (50 mW RF415)
- Receiver sensitivity -110 dBm at 10⁻⁴ bit error rate
(-104 dBm for RF415)
- Antenna impedance 50 Ω , unbalanced (SMA male connector)
- Interference reject 70 dB at pager and cellular phone frequencies (RF400/RF410)
- RF packet size up to 64 bytes, half-duplex
- Error handling RF packet CRC failure detection/rejection or configurable retry levels

3. Quick Start



This section is intended to serve as a “primer” enabling you to quickly build a simple system and see how it operates. This section describes in four steps how to set up a pair of RF400s in a direct connect, point-to-point network. We recommend that you do this before undertaking field installation. For additional help on point-to-point networks and for help on creating point-to-multipoint networks, refer to Software Setup Section 5.

For this system you will need the following hardware or the equivalent:

1. Two RF400s
2. Two RF400 antennas
3. AC adapter (Item # 15966 or part of kit #14220)
4. Serial cable (6 ft.) for PC COM port to RF400 RS-232 port (Item # 10873 or part of Item # 14220)
5. SC12 cable (included with RF400)
6. Datalogger (CR10X, CR510, or CR23X)
7. Field Power Cable (Item # 14291) if datalogger or wiring panel doesn't have 12 V on pin 8 of CS I/O port

You will also need:

1. An IBM[™] compatible PC with one available COM port
2. LoggerNet or PC208W installed

Step 1 – Set Up Base RF400

- a. Connect an antenna (or antenna cable with yagi or omni directional antenna attached) to the RF400 antenna jack. Any RF400 antenna will work at close range in any orientation. The main objective is to provide an antenna. If you should transmit without an antenna attached, there will be no equipment damage as the transmitter is protected against load mismatch. The separation between the base RF400 antenna and the remote RF400 antenna can be any convenient distance.
- b. Connect 6 ft. serial cable from PC COM port to base RF400 RS-232 port.
- c. Plug AC adapter into AC outlet and plug barrel connector into base RF400 "DC Pwr" jack. You will see the red "Pwr/TX" LED light immediately followed by the green RX LED in about 5 seconds. The green LED goes off after a second and the red after ten seconds indicating a successful power-up. The red LED then begins to flash on and off. The red LED flashes once every half second in the default "< 4 mA, ½ sec Cycle" standby mode as the RF400 wakes up briefly and listens for RF transmissions with an average current consumption less than 4 mA.
- d. Use default settings of RF400.

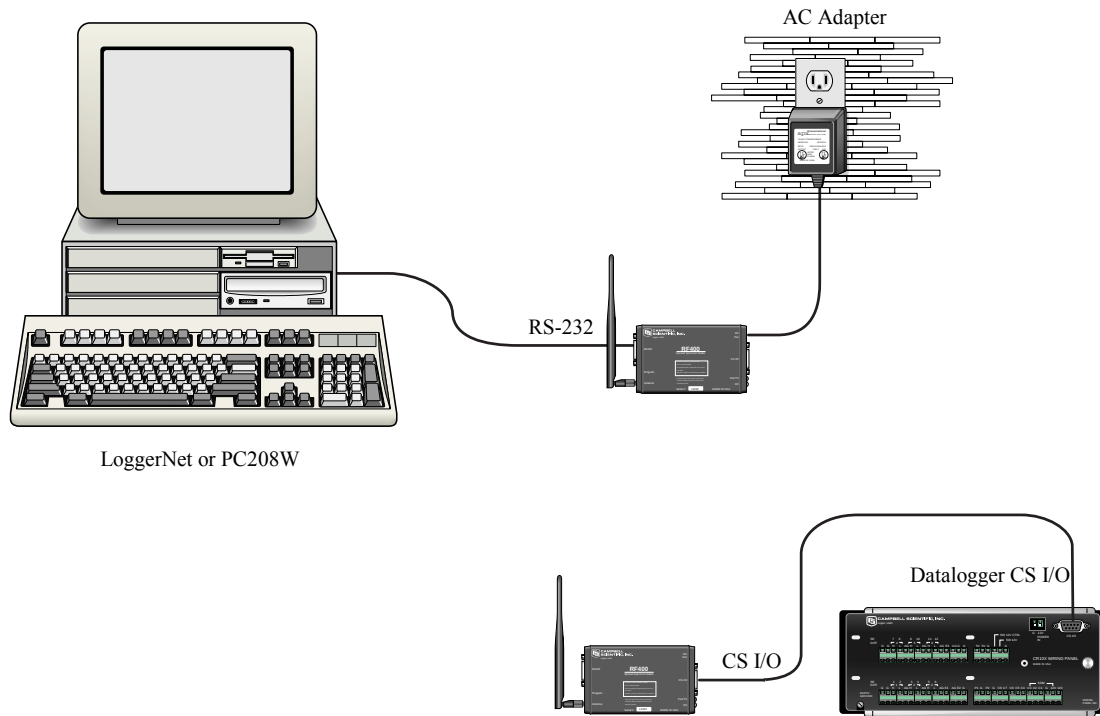


FIGURE 2. RF400 Basic Point-to-Point Network

Step 2 – Set Up Remote RF400

- Connect an antenna (or antenna cable with yagi or omni directional antenna attached) to the RF400 antenna jack. The separation between the base RF400 antenna and the remote RF400 antenna can be any convenient distance.
- Connect SC12 serial cable from datalogger CS I/O port to remote RF400 CS I/O port. Current datalogger/wiring panel CS I/O ports apply power to the remote RF400.

With older dataloggers lacking 12 V on pin 8 (see Table 1), you can power the RF400 using a Field Power Cable (see above hardware list) between the datalogger's 12 V (output) terminals and the RF400's "DC Pwr" jack.

TABLE 1. Lacking 12 V on CS I/O Pin 8	
EQUIPMENT	SERIAL NUMBER
CR500	< 1765
CR7 700X Bd.	< 2779
21X	< 13443
CR10 Wiring Panels	All (black, gray, silver)
PS512M Power Supply	< 1712

When you connect power to the RF400 (through the SC12 cable or the optional Field Power Cable) you should see the power-up sequence of red and green LEDs described in Step 1 (assuming datalogger is powered).

Current dataloggers and wiring panels (not mentioned in Table 1) provide 12 V on pin 8. For older products not listed, check for 12 V between CS I/O connector pin 8 and pin 2 (GND) or contact Campbell Scientific.

- c. Use default settings of RF400.

Step 3 – LoggerNet/PC208W Set-up

- a. The next step is to run LoggerNet/PC208W and configure it to connect to the datalogger via the RF400 point-to-point network you have set up. The RF400 in a point-to-point network can operate transparent to LoggerNet/PC208W. Simply add a datalogger to a COM port in the Device Map.

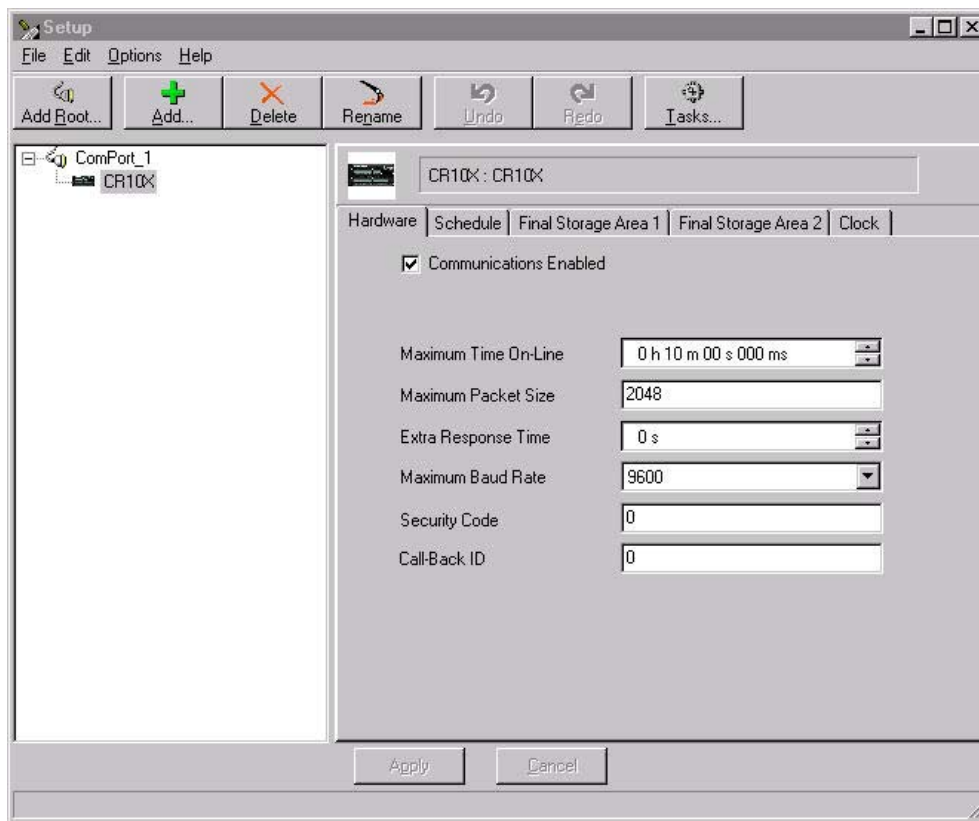


FIGURE 3. Point-to-Point LoggerNet Network Map

- b. Set the Maximum Baud Rate for 9600 baud which is the rate at which the RF400 communicates by default. The datalogger “Extra Response Time” can be left at 0.

CAUTION

For safety, maintain 20 cm (8 inches) distance between antenna and any nearby persons while RF400 is transmitting.

Auto Sense

The RF400 has a default feature called “Auto Sense” that automatically configures certain RF400 settings. When you connect an RF400 to a datalogger (CS I/O port to CS I/O port) the RF400 detects the presence of the datalogger and makes its CS I/O port the active port. When you are not connected to a datalogger’s CS I/O port, Auto Sense detects that and configures its RS-232 port as the active port and configures certain other settings so it can serve as a base RF400.

For point-to-point networks Auto Sense and default settings take care of everything. An exception to this is where you have a neighboring network that is also using the default RF400 settings. In this case, refer to Software Setup Section 5 and change your RF400s to a hopping sequence different than the default settings of “0” (zero). For this point-to-point network, configure both RF400s the same.

Radio Address

Each RF400 has a “Radio Address” that can be changed by the user. In order for two RF400s to communicate, their radio addresses must be set to the same number. The RF400’s factory default radio address is “0” (zero) so a pair of RF400s will be able to communicate out of the box (their network addresses and hopping sequences are also “0” (zero) by default). See Section 4.1.3.1 and Section 5 (Software Setup) for more details.

Step 4 – Connect

You are now ready to Connect to your datalogger using the LoggerNet/PC208W Connect screen. After you connect, notice the flashing of the green LEDs on both RF400s. This indicates that RF packets with the same hopping sequence are being received by the RF400s. The red LEDs light solid while the connection lasts. When you Disconnect, the red LEDs remain on for five seconds, which is the default setting of the “Time of Inactivity to Sleep.”

Datalogger program transfer and data collection are now possible. Refer to Appendix H for a treatment of communication distance vs. factors in the RF path.

4. System Components

4.1 RF400 Series Data Radios

4.1.1 Indicator LEDs

The RF400 has a red LED labeled “Pwr/TX” and a green LED labeled “RX.” When 12V power is applied the red LED lights for ten seconds. About 5 seconds after power-up the green LED lights for a second. Ten seconds after power-up the selected standby mode begins to control the red LED. The red LED lights to indicate when the receiver is actively listening. When the receiver detects RF traffic (header or data with the same hopping sequence), the red LED will light steadily. When the RF400 is transmitting, the red LED will pulse OFF as the RF packets are transmitted (it will not be on solid).

Green LED activity indicates that there is an RF signal being received whose hopping sequence corresponds to the configured hopping sequence of the RF400. This does not necessarily mean that the network/radio address of the received packet corresponds with that of the RF400 (where a neighboring network exists it is a good idea to choose a unique hopping sequence).

4.1.2 Setup Menu

The RF400 has a built-in Setup Menu for configuring active interface, RS-232 properties, network/radio addresses, hopping sequence, power saving (standby) modes, address masks, and other parameters. The Setup Menu is accessed by connecting the radio's RS-232 port to a PC running a terminal program such as Hyper Terminal™ or Procomm™ (always 9600 baud, 8-N-1) and pressing the "Program" button on the RF400 for one second. Changed settings are saved in flash memory by selecting menu item "5" as you exit the Setup Menu. If left idle, the Setup Menu will time out 60 seconds after the last received character and exit without saving any parameter changes with the message "Config Timeout." A datalogger can remain connected to the CS I/O port while setting RF400 parameters on the RS-232 port, although CS I/O communications would be inactive until exiting the Setup Menu.

4.1.2.1 Auto Sense

The factory default setting for Active Interface is "Auto Sense." It is designed to automatically configure an RF400's port and radio address mask for common user situations. When selected, Auto Sense determines whether or not a datalogger (or PS512M null modem) is connected to the RF400 by monitoring for 5 V on CS I/O pin 1. If 5 V is present, Auto Sense selects the RF400's CS I/O port and a radio address mask appropriate for a remote station. Not finding 5 V on CS I/O pin 1, Auto Sense selects the RS-232 port and a radio address mask appropriate for a base station (see Section 4.1.3.1 and Appendix C for more information on radio address masks).

4.1.2.2 Standby Modes

The RF400's average idle current can be set with the following Standby Modes (default setting shaded):

TABLE 2. Standard Setup Menu					
Duty Cycle	Standby Mode Menu Selection	Advanced Standby Mode	Avg. Receive Current	Wake-up Interval (red LED flash interval)	Maximum Response Delay*
100%	1	0	< 24 mA	0 sec (constant)	100 mS
17%	2	4	< 4 mA	½ sec	600 mS
4%	3	6	< 2 mA	1 sec	1100 mS
2%	4	7	< .4 mA	8 sec	8100 mS

*Maximum time it takes to get an RF Packet sent and for the other RF400 to respond.

The Standard Setup standby modes automatically configure:

- Time of Inactivity to Sleep
- Time of Inactivity to Long Header
- Long Header Time

The default mode is the Standard Setup menu selection “2” for “< 4 mA and ½ sec Cycle.” There are standby modes available in addition to those in the above table. They can be accessed in the Advanced Setup menu; however, if you configure one of those, it will be necessary to also configure each of the three bulleted parameters above. In any case, be sure to select the same Standby Mode for all of the RF400s in the network. For more details see Appendix D.

4.1.3 Networking

The RF400 acts as a transparent radio link. Each radio has a configurable network address, radio address, and hopping sequence, and only radios that have the same network address, radio address, and hopping sequence will receive each other’s transmissions. The exception to this is that an RF400 base station can *receive* packets from multiple remote station’s if the base station’s Radio Address Mask is other than the maximum allowed number of 3ffh (hexadecimal). When Auto Sense is selected, it sets the Radio Address Mask to 0h if no 5 V is detected on its CS I/O port pin 1 (see Auto Sense Section 4.1.2.1).

4.1.3.1 Address and Address Mask

For simple point-to-point installations the RF400’s default settings (including address settings) should work unless there is a neighboring network which uses default settings. In that case the network address and, preferably, your hopping sequence should be set to different numbers than the neighboring network uses. A different network number is sufficient but a different hopping sequence (there are 7 available) will result in fewer retries.

The RF400 has a two-part address. When the RF400’s Radio Address is appended to its Network Address you have the complete 16-bit address.

<u>Network Address</u>	<u>Radio Address</u>	
(0 – 63)	(0 – 1023)	decimal
(0 - 11,1111)	(0 - 11,1111,1111)	binary
(3f)	(3ff)	hexadecimal

When an incoming packet arrives from another RF400 using the same hopping sequence, the receiving RF400 compares the packet header’s 16-bit address to its own 16-bit address. If they match, and there are no packet errors, the receiving RF400 sends the packet data to the configured active port (CS I/O or RS-232). This assumes a receiving RF400 address mask of ffffh. If other than ffffh (1111,1111,1111,1111 binary), only those address bits that correspond to address mask “1” bits will be used in the comparison. See Appendix C for details.

4.1.3.2 ATDT Command Mode

This mode is not required for basic point-to-point communication.

For point-to-multipoint operation the RF400 can temporarily be put into AT Command Mode by sending a string of three ASCII characters. The default sequence to enter AT Command mode is:

1. No characters sent for one second (before command character)
2. “+++”characters sent (default command mode entry character)
3. No characters sent for one second (after command mode character)
4. RF400 responds by sending “OK” <CR>

The AT Command mode characters are sent by PC208W along with other commands to change the base RF400’s Radio Address to talk to the desired remote RF400 (see point-to-multipoint example in Software Setup Section).

4.1.3.3 Combination Mode Communications

Besides the “direct” to PC communications described in the Quick Start and Installation sections, it is possible to combine methods in datalogger communications. Some examples:

- Phone to RF400: PC to external modem to COM210 w/PS512M to RF400 to datalogger (see Appendix I)
- Short Haul modem to RF400: PC to short haul modems to RF400s to datalogger (see Appendix G)
- Network to RF400: PC to Internet to NL100 to RF400 to datalogger (use LoggerNet IPPort or PC208W socket, remote IP address, port number)

4.1.4 Error Handling and Retries

In the RF module received packets are analyzed for data corruption with an embedded CRC. The RF400 rejects a received packet (doesn’t send it out a port) if the packet’s header address fails to match the RF400 address, if an RF module receive error is detected, or if the RF packet’s CRC test fails.

In early RF400s no notification was given when a packet was rejected, and there were no retries nor guaranteed delivery of packets. Retries were handled by protocols in LoggerNet and PC208W. Starting with SW Version 6.420 the RF400 series radios themselves are capable of doing retries in a network with an unlimited number of array-based stations or in a network consisting of two PakBus stations.

4.1.4.1 Standard Retry Levels

There are four pre-programmed Retry Levels available in the Standard Setup menu. All RF400s in the network should be configured for the same Retry Level. The default setting is “None.” The standard settings should satisfy most application requirements. Further choices are available in the Advanced Setup menu. All radios in a network should have the same “Maximum

Retries”, “Time-slots for Random Retry”, and “Bytes Transmitted before Delay” settings.

STANDARD RETRY LEVELS				
Menu	Retry Level	Maximum Retries	Time-Slots for Random Retry	Bytes Transmitted Before Delay
1	None	0	0	65535
2	Low	3	2	1000
3	Medium	6	3	1000
4	High	10	5	1000

4.1.4.2 Number of Retries

This setting specifies the maximum number of times an RF400 will re-send a packet failing to get an ACK response. The default setting is zero which inactivates retries. The allowable range is 0 to 255. Entering a number greater than zero activates retries. A receiving RF400 responds to the sending radio with an ACK packet for every RF packet that it receives, addressed to it, that has a valid CRC.

4.1.4.3 Number of Time Slots for Random Retry

This setting is active when the Number of Retries is greater than zero. It specifies the number of 38 ms time slots to create among which to randomly re-send a packet which has failed to get an ACK packet response. The allowable range is 0 to 255.

If packets are failing because of periodic noise or signals, specifying more time slots for random retries will improve the chances for successful retry packet delivery. Increasing the number of time slots, however, results in longer average retry delays which could lower data throughput.

4.1.4.4 Number of Bytes Transmitted before Delay

This feature prevents an RF400 Series radio which has lots of data to transfer from tying up a network until it is finished. The range of settings is 1 to 65535. The default value is 65535 (bytes). This setting forces an RF400 to pause long enough, after sending the specified number of bytes, for another radio to send some data.

4.1.4.5 Sync Timer Setting

This setting determines how often sent packets will include hop synchronization information in the headers. The default setting is 0 which specifies that *every* packet will contain hop sync information. A value greater than zero specifies the interval at which a packet will contain hop sync information. The allowable range is 0 to 255 in units of 100 ms. All radios in the network should have the same Sync Timer Setting.

For example, if you input a value of 50, then packets with hop sync info will be sent out every 5 seconds improving (shortening) the response time of a transmit/response sequence. Even though this shortens the time required to send x amount of data, the throughput is still determined by the CS I/O or RS-232 port baud rate setting.

4.1.4.6 Number of Retry Failures

This reading is available in Setup Menu/Advanced Setup/Radio Parameters/Radio Diagnostics. It indicates the number of times that the RF400 has re-transmitted the specified Number of Retries but failed to get an ACK packet from the receiving radio. For example, if the Number of Retries is set to 3, the transmitting radio will send the same packet up to 3 times; each time looking for an ACK packet back from the receiving radio. If it does not receive an ACK packet after sending the packet 3 times, the transmitting radio will increment its Number of Retry Failures count. If a radio is configured to do retries, it will produce an ACK packet for every RF packet that it receives, addressed to it, that has a valid CRC. If 0 retries are configured, the receiving RF400 will simply throw away any packet that fails the CRC. This reading is cleared upon exiting Setup Menu or cycling RF400 12 V power.

4.1.5 Received Signal Strength

Beginning with SW Version 6.420 the RF400 series radios provide a means of knowing the signal strength of the last packet received, addressed to it, that had a valid CRC. To see this reading enter the RF400's Setup Menu /Advanced Setup/Radio Parameters/Radio Diagnostics menu. RSS readings are cleared upon exiting the Setup Menu or cycling the RF400's 12 Volt power.

The RSS reading is a relative signal level indication expressed in dB (decibels). Readings may vary up to 10 dB from radio to radio for a given received signal level. The weakest signal reading is around 25 dB and the strongest signal reading is near 86 dB. Although the RSS readings are not *absolute*, they will be of value in such activities as:

- determining the optimal direction to aim a yagi antenna
- seeing the effects of antenna height, location
- trying alternate (reflective) paths
- seeing the effect of seasonal tree leaves

4.2 Power Supplies

The typical base station RF400 connected directly to a PC uses a 120 VAC wall adapter to supply 12 VDC power. You can order the optional Base Cable/Power Kit (CSI Item # 14220) to obtain the wall adapter with 6 ft. serial cable. In a phone to RF400 base station configuration (without datalogger) the RF400 can obtain power from a PS512M null modem.

The typical remote RF400 will be connected to a datalogger CS I/O port and get its 12 V power from that. If your datalogger is an earlier unit without 12 V on CS I/O pin 8 (see Table 1), there is an optional Field Power Cable available

(CSI Item # 14291) with tinned leads to connect to power at the datalogger 12 V output terminals and barrel connector to plug into the RF400's "DC Pwr" jack. If 120 VAC is available at the site, the 120 VAC adapter alone (CSI Item # 15966) is an option.

A 12 V supply may connect to either the RF400's "DC Pwr" jack or CS I/O pin 8 (or both, since there is diode isolation between supply inputs). The 12 V supply inputs are diode protected against the application of reverse polarity power.

CAUTION

There are many AC adapters available with barrel connectors (plugs) that will fit the RF400. Some of these (including the CSI AC adapter Item # 272) will cause immediate damage if plugged into the RF400 even briefly. It is also possible to damage the RF400 with an AC adapter labeled as low as "12 VDC" because it may output an open-circuit (no current drain) voltage exceeding the maximum. The very low quiescent current (170 uA) of the RF400 in its default and other standby modes allows the supply voltage to rise at times virtually to its open-circuit level.

**The RF400 series radio will sustain damage if
the DC Pwr jack voltage ever exceeds 18
Volts!**

120 VAC line voltages vary from location to location and from time to time so observing a 16.5 VDC maximum is wise. Unconsidered AC adapter selection raises the specter of over-voltage damage to the RF400 and non-warranty repairs!

There are several things to consider. Beware of AC adapters outputting an AC voltage. An AC adapter can output the correct voltage but the wrong polarity. The center conductor of the barrel connector must be positive (+). The AC adapter must also be capable of supplying the instantaneous peak currents demanded by the RF400 transmitter. The best approach is to obtain the AC adapter recommended by CSI (Item #15966 or the RF400 Base Station Cable/Power Kit Item # 14220 which contains it). If this is not possible, obtain an AC adapter that matches the voltage vs. current characteristics shown below.

To be sure that the candidate AC adapter's "no load" voltage is below the 16.5 VDC recommended maximum, measure the output with a DC voltmeter while the AC adapter is plugged into the outlet but not powering anything.

CSI AC adapter Item # 15966 voltage regulation (typical) while plugged into an AC outlet delivering 120.0 VAC:

TABLE 3. 15966's Voltage Regulation		
Current Drain (mA)	Resistive Load (Ohms)	AC Adapter Output (Volts)
0 (no load)	∞ (open circuit)	12.22
122	100 Ω	12.20
807	15 Ω	12.11

The voltage regulation of the 15966 is exceptionally good.

Power connector polarity: inner conductor positive (+)



TABLE 4. RF400 Series 12 V Power Supply Options		
Network Role	RF400 Connection	Options — CSI Item #
Base	Direct to PC	AC Adapter – 14220 (with serial cable) – 15966 (adapter only)
	Datalogger	<u>If 12V on pin 8*</u> CS I/O Port** <u>If no 12V on pin 8</u> Field Power Cable – 14291 AC Adapter – 14220 (in base cable/power kit) – 15966 (adapter only)
	PS512M	PS512M null-modem connectors
Remote	Datalogger	<u>If 12V on pin 8*</u> CS I/O Port <u>If no 12V on pin 8</u> Field Power Cable – 14291 AC Adapter – 14220 (in base cable/power kit) – 15966 (adapter only)

* See Quick Start – Section 3, Step 2, Table 1

** If powering RF400 from CS I/O port but communicating via RS-232 port, be sure to select “RS-232” as the Active Interface so CS I/O port is not auto selected by Auto Sense.

4.3 Serial Cables

In an RF400 base station, a straight-through DB9M/DB9F RS-232 cable will connect from the RF400's RS-232 port to the PC COM port. This cable is part of the optional Base Cable/Power Kit (CSI Item # 14220).

A remote RF400 normally uses the included SC12 cable to connect the RF400's CS I/O port to the datalogger's CS I/O port.

A remote RF400 can be connected to a CR23X's or CR5000's RS-232 port with a null modem DB9M/DB9M cable (CSI Item # 14392). See Appendix F for details on power supply.

4.4 Antennas for the RF400 Series

Several antennas are offered to satisfy the needs for various base station and remote station requirements. These antennas have been tested at an authorized FCC open-field test site and are certified to be in compliance with FCC emissions limits. All antennas (or antenna cables) have an SMA female connector for connection to the RF400. The use of an unauthorized antenna could cause transmitted field strengths in excess of FCC rules, interfere with licensed services, and result in FCC sanctions against user.

NOTE

An FCC authorized antenna is a REQUIRED component. You must pick one of the antennas listed below.

<u>CSI Item Number</u>	<u>Description</u>
14310	0 dBd ANTENNA, 900 MHZ, OMNI ¼ WAVE WHIP, RPSMA STRAIGHT, LINX, 3.2 inches long.
14204	0 dBd ANTENNA, 900 MHZ, OMNI ½ WAVE WHIP, RPSMA RT ANGLE, ASTRON, 6.75 inches long.
14221	3 dBd ANTENNA, 900 MHZ, OMNI COLLINEAR, ANTENEX FG9023, 24 inches tall, W/FM2 MOUNTS, fits 1 in. to 2 in. O.D. mast (requires COAX RPSMA-L or COAX NTN-L)
15970	1 dBd ANTENNA, 900 MHZ, INDOOR OMNI ½ WAVE DIPOLE, 10 ft. cable with SMA connector to fit RF400 Series, window or wall mounted by sticky back, 4 inches wide.
14205	6 dBd ANTENNA, 900 MHZ, YAGI, LARSEN YA6900 TYPE N-F, boom length 17.25 inches, longest element 7.25 inches, W/MOUNTS, fits 1 in. to 2 in. O.D. mast (requires COAX RPSMA-L or COAX NTN-L)
14201	9 dBd ANTENNA, 900 MHZ, YAGI, MAXRAD BMOY8905 TYPE N-F, boom length 21.4 inches, longest element 6.4 inches, W/MOUNTS, fits 1 in. to 2 in. O.D. mast (requires COAX RPSMA-L or COAX NTN-L)
16005	0 dBd ANTENNA, 2.4 GHz, OMNI ½ WAVE WHIP, RPSMA RT ANGLE, LINX ANT-2.4-CW-RCT-RP, 4.5 inches long.
16755	13 dBd ANTENNA, 2.4 GHz, ENCLOSED YAGI, allows vertical or horizontal polarization, MAXRAD

	WISP24015PTNF, boom length 17 inches, diameter 3 inches, W/ END MOUNT to fit 1 to 2 in. O.D. mast (requires either (1) COAX RPSMA-L for short runs or (2) COAX NTN-L with Antenna Surge Protector Kit)
COAX RPSMA-L	LMR 195 ANTENNA CABLE, REVERSE POLARITY SMA TO TYPE N MALE
COAX NTN-L	RG8 ANTENNA CABLE, TYPE N MALE TO TYPE N MALE CONNECTORS, REQUIRES 14462
14462	ANTENNA SURGE PROTECTOR KIT

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Changing the antenna on a transmitter can significantly increase, or decrease, the strength of the signal that is ultimately transmitted. Except for cable locating equipment, the standards in Part 15 are not based solely on output power but also take into account the antenna characteristics. Thus, a low power transmitter that complies with the technical standards in Part 15 with a particular antenna attached can exceed the Part 15 standards if a different antenna is attached. Should this happen it could pose a serious interference problem to authorized radio communications such as emergency, broadcast, and air-traffic control communications.

CAUTION

In order to comply with the FCC RF exposure requirements, the RF400 series may be used only with **approved antennas** that have been tested with this radio and a minimum separation distance of 20 cm must be maintained from the antenna to any nearby persons.

Read Appendix A of this manual for important FCC information.



ITEM # 14310 900 MHZ OMNI ¼ WAVE WHIP 0 dBd



ITEM # 14204 900 MHZ OMNI ½ WAVE WHIP 0 dBd



ITEM # 14201 900 MHZ YAGI 9 dBd w/MOUNTS



ITEM #14205 900 MHz YAGI 6 dBd w/MOUNTS



ITEM # 14221 900 MHZ OMNI COLLINEAR 3 dBd w/MOUNTS



ITEM #15970 900 MHZ Indoor OMNI 1 dBd Window/Wall Mounted



ITEM #16005 2.4 GHz OMNI HALF WAVE WHIP 0 dBd



ITEM #16755 2.4 GHz ENCLOSED YAGI, 13 dBd w/MOUNTS

FIGURE 4. Some FCC Approved Antennas



FIGURE 5. Example COAX RPSMA-L Cable for Yagi or Omni Colinear



FIGURE 6. Antenna Surge Protector

4.5 Antenna Cables and Surge Protection

4.5.1 Antenna Cables

The 14201, 14203, 14205, 14221, and 16755 antennas require an antenna cable; either (1) the COAX RPSMA or (2) the COAX NTN with surge protector. Indoor omni-directional antennas are either supplied with an appropriate cable or connect directly to the RF400 series radio.

4.5.2 Electro-static Issues

Many RF400 series installations are out of doors and therefore susceptible to lightning damage, especially via the antenna system. Also, depending on climate and location, electro-statically charged wind can damage sensitive electronics if sufficient electric charge is allowed to accumulate on the antenna and cable. To protect against this CSI offers the Item # 14462 Antenna Surge Protection Kit.

The COAX NTN-L cable is a low-loss RG8 coaxial cable that requires the 14462 surge protector in order to connect to an RF400 series radio. The RG8 / Antenna Surge Protector are recommended in preference to the COAX RPSMA in the following applications:

- When the antenna cable length exceeds 10 feet

- When use of COAX RPSMA would result in too much signal loss (see page H-3)
- When the RF400 series radio will be used in an environment susceptible to lightning or electro-static buildup

4.5.3 Antenna Surge Protector Kit

The Surge Protector Kit for the RF400 series radios includes the following:

- Polyphaser protector
- 18 inches of COAX RPSMA to connect ‘tail end’ of surge protector to RF400
- Ground wire lead
- Screw and grommet to secure ground wire and polyphaser to backplate of enclosure

The surge protector has female type N connectors on both ends; one for connection to the COAX NTN-L cable and the other for connection to the 18 inch length of COAX RPSMA cable included in the kit. The COAX RPSMA cable is an LMR195 type that terminates in a type N Male connector on the ‘antenna end’ and a Reverse Polarity SMA (RPSMA) connector on the RF400 end.

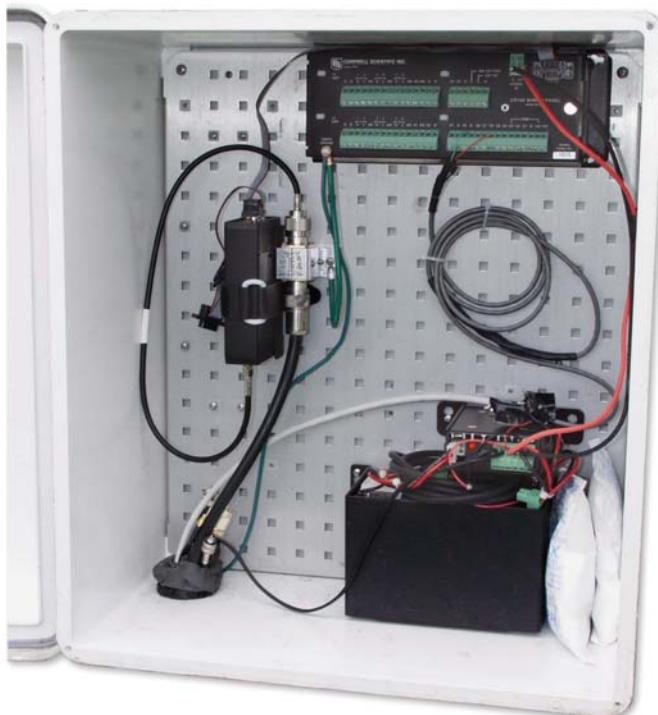


FIGURE 7. Enclosure with Antenna Surge Protector for RF400

5. Software Setup

5.1 Point-to-point

Set-up parameters are configured the same for the two RF400s. The RF400 defaults to radio address “0” (zero) which works for many applications.

See Section 4.2 for power supply options.

5.2 Point-to-multipoint

The radio addresses for a base RF400 and its remotes are typically configured to be different from one another. The base RF400 radio address might be 0, the first remote’s radio address might be 1, and the second remote’s radio address might be 2, etc.

For the base RF400 to be able to transmit to a remote RF400, the base’s Radio Address must be temporarily changed to match that of the remote. The address change is done by putting the base RF400 into command mode, changing the address with an ATDT command, and then putting it back into data mode with the ATCN command. You can accomplish this by entering these commands in the Generic Dial String in PC208W’s datalogger Setup Connections screen (see example below).

See Section 4.2 for power supply options.

5.3 Example Setups

The following procedures explain how to build a basic RF400 point-to-point network and a point-to-multipoint network with base station connected directly to the PC COM port. The PC should be running LoggerNet or PC208W. The remote station can consist of an RF400 connected to a datalogger.

5.3.1 Direct PC to RF400 Series Base Station Setup

1. Connect the RF400’s RS-232 port to a PC COM port using a straight through serial cable Item # 10873, or equivalent. Use a 25-pin to 9-pin adapter if necessary. This hardware configuration can serve (1) to do the set-up of the RF400, and (2) for base station communications with datalogger(s) in point-to-point or point-to-multipoint networks.
2. Run Hyper Terminal™, Procomm™, or other terminal emulator program.
 - a. Baud rate: 9600, 8-N-1
 - c. Flow control: none
 - d. Emulation: TTY
 - e. ASCII (raw)
 - f. COM1 (direct connect)
3. Power up RF400 (wait two seconds) and press “Program” button for one second to see the following display.

Main Menu

SW Version 6.425 (for example)

(1) Standard Setup

(2) Advanced Setup

(3) Restore Defaults

(4) Show All Current and Default Settings

(5) Save All Parameters and Exit Setup

(9) Exit Setup without Saving Parameters

Enter Choice:

4. Press “1” for Standard Setup
Display:

Standard Setup:	Current Setting
(1) Active Interface	Auto Sense
(2) Net Address	0
(3) Radio Address	1
	(Net + Radio Address 0h)
(4) Hopping Sequence	0
(5) Standby Mode	< 4 mA, ½ sec Cycle
(6) Retry Level	
(9) Return to Main Menu	

Enter Choice:

- a. Leave Active Interface in “Auto Sense” (default setting) for most applications. In Auto Sense the RF400 will test for 5 V on CS I/O port (pin 1) to determine if a datalogger is present and if so select the CS I/O port.
- b. Select a Net Address from (0 – 63). Unless there is a neighboring network, leave network address “0.” The Network Address must be the same throughout the network of RF400s.

- c. Select a Radio Address (0 – 1023). The radio addresses must be the same in point-to-point communications (for point-to-multipoint communications you could set the base RF400 to 0 and the remotes to 1, 2, 3, etc.).

It is a good idea to label each RF400 indicating the configured network address, radio address, hopping sequence, etc.

- d. Select a Hopping Sequence (0 – 6). The hopping sequence must be the same for all RF400s in the network.

If there happens to be a neighboring RF400 network using the same hopping sequence, you should change to a different one in case their network and radio addresses happen to match yours and to reduce retries.

- RX LED Test -

To determine if there is a neighboring RF400 network in operation using the same hopping sequence as yours, stop communications on your network and observe an RF400 green LED for activity. A flashing green LED would indicate that there is a nearby network using the same hopping sequence.

- e. Select desired Standby mode (< 24 mA Always on, < 4 mA ½ sec Cycle, etc.) according to your power budget. All RF400s in the network must be in the same Standby Mode. The default setting is a good starting point (< 4 mA ½ sec Cycle).
- f. Select desired Retry Level (None, Low, Medium or High) according to the level of RF ‘collisions’ you expect. This depends on how many neighboring RF400s in and out of your network and the frequency of transmissions. Retries can, for example, reduce pauses in real-time monitoring of Input Locations.
- g. Press 9 to “Return to Main Menu”.
- h. There are other (“advanced”) parameters which typically remain “default” or as set by Auto Sense.
- i. Press “5” to “Save All Parameters and Exit Setup.”

5.3.2 Remote Station Setup

1. Point-to-point
 - a. Complete steps 1 to 4 above making the remote station’s Network Address, Radio Address, and Hopping Sequence the same as the base station’s.
 - b. While in Standard Setup verify that the Active Interface configuration is “Auto Sense” and set the Standby Mode the same as the base RF400 (default “2” ok).
 - c. Exit and Save your configuration by pressing “5”.

2. Point-to-multipoint

- a. Complete steps 1 to 4 above making the remote stations' Network Addresses and Hopping Sequences the same as the base station's.
- b. While in Standard Setup verify that the active interface is "Auto Sense" and give each remote RF400 a unique Radio Address.

You should label each RF400 (with masking tape) indicating the configured network address, radio address, hopping sequence, etc.

- c. Exit and Save your configuration by pressing "5".

3. Antenna considerations

- a. Line of sight – the single most important factor in radio performance is antenna placement. As Appendix H states, "height is everything." The two RF400s must be able to 'see' each other if distances over a mile or two are required. This can be accomplished with a mast or tower.
- b. Mounting – the higher the gain of a yagi antenna, the more important it is to aim the yagi precisely and mount the yagi solidly to prevent movement due to strong winds, large birds, etc.
- c. Antenna cable routing – the antenna cable should be routed in a protected area and made secure against damage from wildlife, wind, and vandalism.
- d. Antenna cable weather sealing – the presence of water inside the antenna cable's plastic sheath can attenuate your transmitted and received signals significantly. The RF energy, instead of traveling the length of the cable with little loss, is absorbed according to the amount of water present (like in a microwave oven). A small amount of water can ruin a once good communication link.

When moisture gets inside the sheath it is very difficult to remove. Some careful cable handling (even pinholes can let in significant amounts of water), thoughtful cable routing, and good weather-proofing can prevent this.

Apply a 1/8 inch thick coat of pure silicone rubber compound (RTV) 1) where the cable connector screws onto the antenna connector (apply after the connector is in place allowing future removal) and 2) at the junction between plastic cable sheath and cable connector. If carefully done this should last for years. An alternative approach is to wrap self-vulcanizing rubber tape around these same areas of the antenna connector, cable connector and cable sheath. This tape can be purchased at most electrical supply stores (see Troubleshooting Section 6, item 6).

4. Site considerations

Location of an RF400 near commercial transmitters, such as at certain mountaintop sites, is not recommended due to possible "de-sensing" problems for the RF400 receiver. A powerful signal of almost any frequency at close range can simply overwhelm a receiver. Lower

power and intermittent repeater sites may not be a problem. Test such a site with a representative setup before committing to it (see Troubleshooting Section 6). Keep in mind that commercial sites tend to evolve. Such a site may work now but could change in the future with the addition of new equipment.

5.3.3 LoggerNet Configuration

There are two ways of configuring the Setup map for a point-to-point 'network.' You can represent the RF400s in the Setup map or simply leave them off. The simple map usually results in a quicker connection and requires less typing.

(1) **Point-to-point** (not represented)

(a) Setup map:

```
ComPort_1
CR10X
```

(2) **Point-to-point** (represented)

(a) Setup map:

```
ComPort_1
RF400
RF400Remote
CR10X
```

(3) The station's Maximum Baud Rate is typically 9600

(4) Extra Response Times are typically 0 s

In the case of point-to-multipoint, the RF400s are always represented in the LoggerNet Setup map so that LoggerNet can temporarily change the base RF400's Radio Address to communicate with one out of a group of remote RF400s.

(1) **Point-to-multipoint**

(a) Setup map:

```
ComPort_1
RF400
RF400Remote_1
CR10X_1
RF400Remote_2
CR10X_2
RF400Remote_3
CR10X_3
```

(2) All RF400Remotes have the same Network Address but each RF400Remote must have a unique Radio Address.

(3) Extra Response Times are typically 0 s

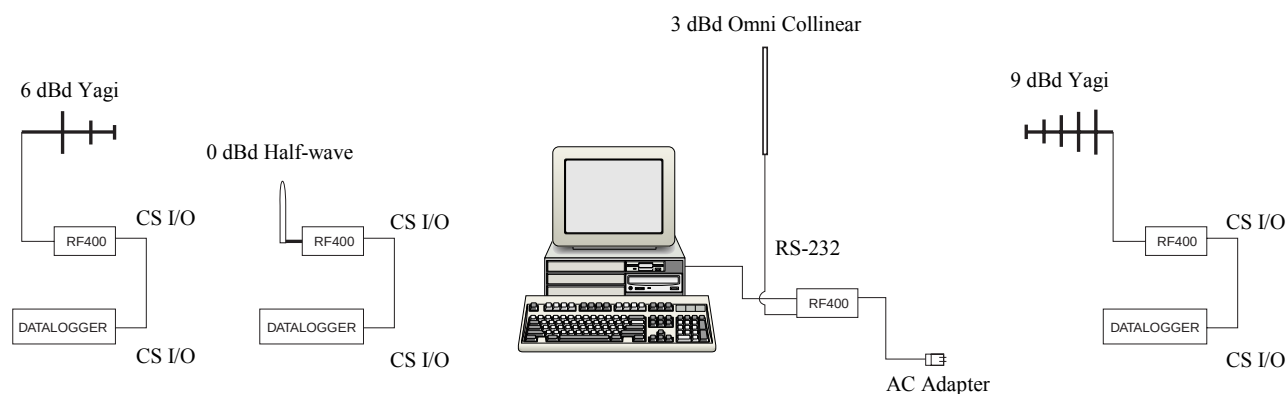


FIGURE 8. Point-to-Multipoint System

5.3.4 PC208W Configuration

a. Point-to-point

- (1) Device Map - COM1
CR10X1
- (2) Set station CR10X1 baud rate to 9600 baud in network map
- (3) Datalogger extra response time – 0 mS

b. Point-to-multipoint

- (1) Device Map - COM1
Generic1
10X3001
10X3005
- (2) Set Generic Modem baud rate to 9600 in device map.
- (3) Generic Modem Settings
 - (a) ✓ “Make DTR Active”
 - (b) ✓ “Hardware Flow Control”
 - (c) Extra Response Time (Standby Mode Max Response Delay + 200 ms; see Table D-1)
 - (i) 0 mS with 24 mA Standby Mode
 - (ii) 1200 mS with 1/2 sec cycle default Standby Mode delay
 - (iii) 4200 mS with 2 sec cycle Standby Mode delay

(4) Datalogger Station Settings

(a) Example “Dialed Using Generic Dial String”:

```
D1000 T"+++" R"OK"9200 T"ATDT3001^m"R"OK"1200
T"ATCN^m"R"OK"1200
```

- (i) D1000 creates a 1 second delay
- (ii) T sends quoted string w/o waiting for a character echo
- (iii) +++ is string sent to put RF400 in AT Command mode (use other character if phone modems in path)
- (iv) R"OK"9200 waits up to 9.2 sec for RF400 “OK” response
- (v) ATDT3001 changes radio address to talk to remote RF400 with network address of 12 and radio address of 1. This is a hexadecimal number (see Appendix C for example combined hexadecimal network/radio addresses) and is calculated by Setup Menu at Main Menu, Standard Setup, Radio Address.
- (vi) ATCN ends RF400 AT Command mode

(b) Datalogger extra response time – 0 mS

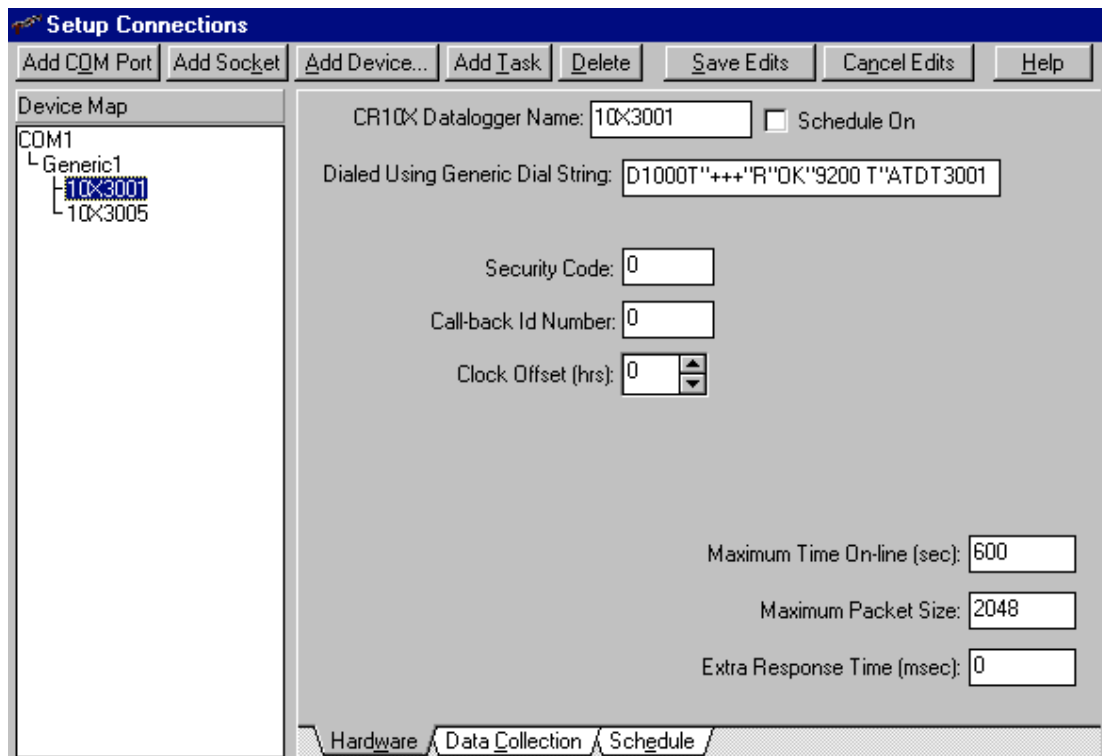


FIGURE 9. PC208W Datalogger Generic Dial String

6. Troubleshooting

If you can't connect, check out these possible causes:

1. Datalogger or Wiring Panel lacks 12 V power on pin 8 of CS I/O port

The RF400 should go through its initialization with red and green LEDs lighting (see Section 4.1.1) when serial cable is connected if 12 V is present on CS I/O connector (see Quick Start Table 1). If needed obtain the optional Field Power Cable (CSI Item # 14291) to connect between datalogger 12 V output terminals and RF400 "DC Pwr" jack to supply power to the RF400.

2. Active Interface set wrong

This setting should normally be "Auto Sense" unless you have a phone to RF400 base station with PS512M and COM210 which requires the "COM2xx to RF400" setting or you have a PakBus datalogger requiring "Datalogger CSDC" due to another M.E. peripheral present. You could set the Active Interface to RS-232 or Datalogger Modem Enable if that is its permanent assignment, otherwise "Auto Sense" may be better.

3. Low or weak battery voltage or 12 VDC supply voltage

The power supply battery may not be charging properly due to solar panel orientation, poor connection, or due to a charging transformer problem. The battery itself may have discharged too low too many times, ruining the battery. Lead acid batteries like to be topped off.

Power supply must be able to sustain at least 9.6 V (datalogger minimum) even during 75 mA transmitter bursts lasting only a few milliseconds.

4. Lightning damage to RF400

Swap in a known good RF400 with the same settings and see if this cures the problem. Lightning damage can occur leaving no visible indications. A "near miss" can cause damage as well as a more direct hit with evidence of smoke (see Appendix K for pass/fail tests).

5. Lightning damage to antenna and/or cable

Swap in a known good antenna and/or cable. Hidden damage may exist.

6. Moisture in coaxial antenna cable

It is possible that moisture has penetrated inside the plastic sheath of the coaxial cable. Water inside the cable can absorb RF energy and attenuate the transmitted signal; the received signal would also be attenuated. It is difficult to dry out the interior of a coaxial cable. Substitution of a dry cable is recommended.

Placing a wet cable in a conventional oven at 160°F for a couple of hours should dry it out. Shield the antenna cable against damage from radiated heat from the oven element by placing the coiled cable on a large cookie sheet or a sheet of aluminum foil. See section 5.3.2 (3.d) for information on weatherproofing the antenna cable.

7. RF400 receiver “de-sensing” from nearby transmitter

This problem can be observed from LED behavior when operating a hand-held radio near an RF400 that is receiving collected data from a remote station. If you key a hand-held 150 MHz or 450 MHz transmitter, even though its frequency of operation is far removed from the 900 MHz band, its close proximity to the base RF400 can overwhelm (de-sense) the RF400 receiver resulting in failed packets and LoggerNet/PC208W retries. This problem could also occur if you located an RF400 at a site containing commercial transmitters or repeaters. In general it is best to avoid such sites, especially the high-power FM or AM transmitter antenna sites which can change at any time with added equipment.

It is possible to avoid de-sensing in some cases if RF400 link is solid enough due to: the proximity of your remote RF400(s); high antenna gains and directionality; high elevation; and sufficient distance separation between RF400 and commercial transmitter antenna. Try horizontal polarization of antennas. A field test in such situations is essential.

8. Insufficient signal strength

There are some things you can try to get that extra few dBs of signal strength sometimes necessary for a dependable RF link. The drop in signal going from Winter (no deciduous tree leaves) to Spring sometimes requires a little more signal.

- a. Raise the antenna height using a mast, tower or higher terrain. Often a little extra height makes the difference.
- b. Change to a higher gain antenna
- c. If in a multi-path situation such as inside a reflective building or canyon, try pointing the antenna in unlikely directions while looping back data (see Pass/Fail Appendix K) from the remote RF400 and typing characters in HyperTerminal™. Sometimes a particular reflected signal will be stronger than the direct wave.
- d. Change polarization (element orientation) of all antennas in your network (yagi or collinear) from vertical to horizontal or vice versa.

9. Interference from 900 MHz transmitter

There are some measures you can take to reduce interference from neighboring 900 MHz transmitters:

- a. Move base station as far as possible from offending transmitter antenna.
- b. Install 9 dBd yagi and position station so that offending transmitter is located behind or to the side of the yagi to take advantage of yagi's front-to-back or front-to-side ratio (back and side signal rejection).
- c. Change polarization (element orientation) of all yagi and collinear antennas in your network to see if that reduces effects of offending transmitter.

10. PC208W.dnd file corrupted

The remote possibility exists that this file has become corrupted in your PC. After you create the Network Map in PC208W, you can back up PC208W.dnd in case this should happen. If this appears likely, exit PC208W and copy and paste your backup file over the suspect .dnd file to restore proper operation.

11. RF400 has wrong Network Address, Radio Address, Hopping Sequence, or Standby Mode

It is improbable that an RF400 that has been working would ever change address, hopping sequence or other settings. However, check the settings for the unlikely event this may have happened. Try “Restore Defaults” and set up RF400 again from that point.

Appendix A. Part 15 FCC Compliance Warning

Changes or modifications to the RF400 series radio systems not expressly approved by Campbell Scientific, Inc. could void the user's authority to operate this product.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

- 1) This device may not cause harmful interference, and
- 2) This device must accept any interference received, including interference that may cause undesired operation.

Appendix B. Setup Menu

Here is the structure of the RF400 series' built-in Setup Menu system which can be accessed by configuring a terminal emulator program such as Procomm™ or HyperTerminal™ to 9600 baud (8-N-1) and pressing the “Program” button on the RF400 with RF400's RS-232 port cabled to appropriate COM port of PC. Also displayed is a number representing the radio's software and RF module versions. For example: 6.425.

MAIN MENU

SW Version 6.425

- 1) Standard Setup
 - a) Active Interface
 - i) Auto Sense
 - ii) RS-232
 - iii) Datalogger Modem Enable
 - iv) Datalogger SDC
(not for Table Based Loggers)
 - v) Datalogger CSDC
(only for Table Based Loggers)
 - vi) COM2xx to RF400
 - b) Net Address (0 – 63)
 - c) Radio Address (0 – 1023)
 - d) Hopping Sequence (0 - 6)
 - e) Standby Mode (select one of the following)
 - i) <24 mA Always On
 - ii) < 4 mA 1/2 sec Cycle
 - iii) < 2 mA 1 sec Cycle
 - iv) < .4 mA 8 sec Cycle
- 2) Advanced Setup
 - a) Radio Parameters
 - i) Radio Address Parameters
 - (1) Net Address
(0 – 63)
 - (2) Radio Address
(0 – 1023)
 - (3) Net Address Mask
(0 – 3fh)
 - (4) Radio Address Mask
(0 – 3ffh)
 - (5) Hop Table
(0 – 6)

- ii) Radio Standby Modes
 - (1) Standby Mode
 - (0 => 24 mA Always ON 3 => 4 mA 1/2 sec Cycle)
 - (4 => 2 mA 1 sec Cycle 5 => 1 mA 2 sec Cycle)
 - (6 => .6 mA 4 sec Cycle 7 => .4 mA 8 sec Cycle)
 - (2) Time of Inactivity to Sleep
(units of 100 msec; 1 – 32767)
 - (3) Time of Inactivity to Long Header
(units of 100 msec; 0 – 65535)
Select 0 to always use long header
Select 65535 to never use long header
 - (4) Long Header Time
(units of 100 msec; 0 – 255)
- iii) Radio AT Command Sequence Setup Menu
 - (1) AT Command Sequence Character
(any ASCII character)
 - (2) Silence time before Command Sequence
(units of 100 msec; 1 – 32767)
 - (3) Silence time after Command Sequence
(units of 100 msec; 1 – 32767)
 - (4) AT Command Mode Timeout
(units of 100 msec; 1 – 32767)
- iv) Radio Diagnostics
 - Number of Retry Failures:
 - Received Signal Strength:
- v) Radio Retry Settings
 - (1) Number of Retries
(0 – 255)
 - (2) Number of time slots for random retry
(units of 38 msec; 0 – 255)
 - (3) Number of bytes transmitted before delay
(1 – 65535)
 - (4) Sync Timer Setting;
(units of 100 msec; 0 – 255)
- b) Interface Parameters
 - i) CSDC Address (Not Active):
(7 or 8)
 - ii) RS-232 Auto Power Down Enable
 - 0 => RS-232 always active to power RS-232 devices
 - 1 => RS-232 TX automatically powers down when no activity for 30 sec
 - iii) RS-232 Parameters
 - (1) RS-232 Baud Rate:
 - 0 => 1200
 - 1 => 4800
 - 2 => 9600
 - 3 => 19.2k

- 4 => 38.3k
- (2) RS-232 Parity:
 - 0 => None
 - 1 => Odd
 - 2 => Even
- (3) RS-232 Character Length:
 - 0 => 8 bits
 - 1 => 7 bits
- (4) RS-232 Stop Bits:
 - 0 => 1
 - 1 => 2
- 3) Restore Defaults
- 4) Show All Current and Default Settings
- 5) Save All Parameters and Exit Setup
- 6) Exit Setup without Saving Parameters

Appendix C. RF400 Series Address and Address Mask

Address

An RF400's address is 16 bits:

(0 - 1111,1111,1111,1111)	binary
(0 - ffffh)	hexadecimal
0 – 65535)	decimal

The two parts of the address are the “Network Address” and the “Radio Address.” The six most significant bits of the address are the “Network Address”, and the ten least significant bits are the “Radio Address.”

<u>Network Address</u>	<u>Radio Address</u>	
(0 - 11,1111)	(0 - 11,1111,1111)	binary
(0 - 3fh)	(0 - 3ffh)	hexadecimal
(0 – 63)	(0 – 1023)	decimal

Address mask

The RF400 has a user programmable 16-bit address mask. Like the address, the address mask is divided into two parts. The six most significant bits are the Network Address Mask and the remaining ten bits are the Radio Address Mask.

When an incoming packet header's address is compared with the RF400's address, only the address bits that correspond to address mask “1”s are used in the comparison.

Example 1

Incoming Packet's Header Address	xxxx xxxx xxxx xxxx
RF400's Network Address Mask	1111 11
RF400's Network Address	YYYY YY
RF400's Radio Address Mask	11 1111 1111
RF400's Radio Address	zz zzzz zzzz

Since the address mask is all “1”s, all of the incoming Packet Header Address bits are compared against the corresponding RF400's address bits.

Example 2

Incoming Packet's Header Address	xxxx xxxx xxxx xxxx
RF400's Network Address Mask	1111 11
RF400's Network Address	YYYY YY
RF400's Radio Address Mask	11 1111 0000
RF400's Radio Address	zz zzzz zzzz

In this example, only the twelve most significant incoming Packet Header Address bits are used in the comparison with the RF400's twelve most significant address bits because the entire address mask (Radio Address Mask appended to Network Address Mask) is 1111,1111,1111,0000. Since the last

four bits are not compared, any remote RF400 with Radio Address of 0 to 1111 (decimal 0 to 15) will be received by the base station.

This allows multiple remotes in a network to be received by the base without changing the base Radio Address (the remotes cannot receive the base, however).

Auto-Sense pre-configures as many settings as possible (including the address mask). If you have an RF400 connected to a PC's RS-232 port and a remote RF400 connected to a datalogger's CS I/O port, Auto-Sense will configure the remote's address mask to (3fh, 3ffh) so that it will only receive a 16-bit address match (Network and Radio), but the base's address mask to (3fh, 0h) so it will receive any packet that has the same Network Address (and hopping sequence) regardless of Radio Address.

Combined Network/ Radio Addresses

If programming PC208W for Point-to-Multipoint networks, the Generic Dial Strings require the combined 16-bit addresses of the RF400s to be called. The RF400 Setup Menu (in Standard Setup, Radio Address) calculates and displays the combined network and radio address when you enter the network and radio address values. Following are some examples.

NET ADDRESS (decimal)	RADIO ADDRESS (decimal)	COMBINED 16-BIT ADDRESS (hexadecimal)
0	0	0000
0	1	0001
0	2	0002
0	3	0003
0	4	0004
0	5	0005
0	6	0006
0	7	0007
0	8	0008
0	9	0009
0	10	000A
0	11	000B
0	12	000C
0	13	000D
0	14	000E
0	15	000F
0	16	0010
0	17	0011
0	18	0012
0	19	0013
0	20	0014
0	21	0015
0	22	0016
0	23	0017
0	24	0018
0	25	0019
0	26	000A
0	27	000B
0	28	000C

NET ADDRESS (decimal)	RADIO ADDRESS (decimal)	COMBINED 16-BIT ADDRESS (hexadecimal)
0	29	001D
0	30	001E
0	31	001F
0	32	0020
0	1022	03FE
0	1023	03FF
1	0	0400
1	1	0401
2	0	0800
2	1	0801
3	0	0C00
3	1	0C01
4	0	1000
4	1	1001
5	0	1400
5	1	1401
6	0	1800
6	1	1801
7	0	1C00
7	1	1C01
8	0	2000
8	1	2001
9	0	2400
9	1	2401
10	0	2800
10	1	2801
11	0	2C00
11	1	2C01
12	0	3000
12	1	3001
13	0	3400
13	1	3401
14	0	3800
14	1	3801

NET ADDRESS (decimal)	RADIO ADDRESS (decimal)	COMBINED 16-BIT ADDRESS (hexadecimal)
15	0	3C00
15	1	3C01
16	0	4000
16	1	4001

Appendix D. Advanced Setup Standby Modes

The Standard Setup menu selections should fill the majority of user needs. The following information is given in case you need to program a non-standard standby mode.

The Standard Setup menu selections do not correspond with Advanced Setup menu entries. For example: selecting a “3” in the Standard Setup menu selects (< 2 mA 1 sec Cycle) whereas entering a “3” in the Advanced Setup menu selects (< 4 mA 1/2 sec Cycle).

Table D-1. Advanced Setup Menu			
STANDBY MODE	STANDBY AVG RECEIVE CURRENT	Wake-up Interval (red LED flash interval)	MAX. RESPONSE DELAY
0 ¹	< 24 mA	0 (constant)	0 sec
1			
2			
3 ²	< 4 mA	½ sec	½ sec
4 ³	< 2 mA	1 sec	1 sec
5	< 1 mA	2 sec	2 sec
6	< 0.6 mA	4 sec	4 sec
7 ⁴	< 0.4 mA	8 sec	8 sec

Shaded modes 1, 2 not available

¹ Standard Setup menu selection 1

² Standard Setup menu selection 2

³ Standard Setup menu selection 3

⁴ Standard Setup menu selection 4

Standard Setup automatically configures the following three parameters appropriately. If you configure a standby mode from the Advanced Setup menu you must also manually configure these parameters according to the following guidelines:

- (1) Time of Inactivity to Sleep
- (2) Time of Inactivity to Long Header
- (3) Long Header Time

The first two parameters should be set to about the same value. What this value is will depend upon the nature of the anticipated activity. The defaults are 5 seconds and 4.8 seconds, so if you go more than 4.8 seconds without activity, a long header is sent, and a corresponding 5 second receive delay will be experienced.

In general, these inactivity timers should be set so that the RF400 stays on (receiving or transmitting, not in standby mode) longer than the quiet times during communication. You can experiment with this to see how it works.

TIME OF INACTIVITY TO SLEEP

The amount of receiver inactivity time desired before entering Standby Mode. This number is only valid in receive and duty cycling modes. Valid numbers range from 1 to 65535. The default number is 50 (for 5 seconds).

TIME OF INACTIVITY TO LONG HEADER

Set time before Long Header occurs. The time of inactivity on the wireless modem's receive pin before a long header is issued. The valid number range is from 0 to 65535. 65535 selects no long header at all. The default is 48 (for 4.8 seconds).

LONG HEADER TIME

Sets long header duration in tenths of a second. The default is 7 (for 0.7 seconds). If changed from the default of 7, this number should be set to half of the "Delay" indicated in the Standby Mode you are using + 200 ms. For example, if your standby mode Delay is 4 seconds, set the Long Header Time to 22 (tenths of a second) for 2.2 seconds. The valid number range is from 0 to 255. The longest long header time you should ever need is 8.2 seconds.

Appendix E. RF400 Series Port Pin Descriptions

RS-232 Port

The “RS232” port is a partial implementation of RS-232C. It is configured as Data Communications Equipment (DCE) for direct cable connection to Data Terminal Equipment (DTE) such as an IBM-PC serial port.

RS-232 CONNECTOR, 9-PIN D-SUB FEMALE

PIN	I/O	DESCRIPTION
1		
2	O	TX
3	I	RX
4		
5		GND
6		
7		
8	O	CTS
9		

I = Signal Into the RF400, 0 = Signal Out of the RF400

Only CTS is implemented for flow control. If data arrives (say from a PC) faster than the RF400 transmits it, the RF400 will de-assert CTS when the 640 byte port buffer is full. If the PC continues to send data, the buffer will accept it and may wrap around over-writing oldest data. PC208W and LoggerNet monitor CTS to prevent buffer over-run.

The RF400 can transmit RF packets slightly in excess of 9600 baud. When RF packets are received by the RF400, that data is immediately sent to the “active interface” port without flow control (no RTS).

For many applications the RF400 works fine with no flow control. The need for flow control arises when longer standby modes are used, where more data could be sent than the 640 byte buffer can hold before transmittal. For example, if the RF400s are in Standby Mode 6 (see Appendix D), an RF400 needs to buffer incoming RS-232 data for up to 8 seconds while waiting for the other RF400 to wake up before transmitting it. Also, if the RF400 is doing a lot of retries, that can take extra time and require flow control to avoid buffer over-run.

CS I/O Port

The CS I/O port is Campbell Scientific's input/output port. It is not a standard RS-232 pin-out. The following table provides pin-out information on the port when connected to a datalogger.

CS I/O CONNECTOR, 9-PIN D-SUB MALE

PIN	FUNCTION	I/O	DESCRIPTION
1	5V	I	Sources 5 VDC to power peripherals
2	GND		GND for pin 1 and signals
3	Ring	O	Raised by modem to put datalogger into telecommunications mode
4	RX	O	Serial data receive line
5	Modem Enable	I	Raised when datalogger determines that associated modem raised the ring line
6	Synchronous Device Enable	I	Used by datalogger to address synchronous devices; can be used as a printer enable
7	CLK/Handshake	I/O	Used by datalogger with SDE and TX lines to transfer data to synchronous devices
8	12V supplied by datalogger	PWR	Sources 12 VDC to power peripherals
9	TX	I	Serial data transmit line

I = Signal Into the RF400, 0 = Signal Out of the RF400

Appendix F. Datalogger RS-232 Port to RF400 Series Radio

A connection from RF400 RS-232 port to CR23X or CR5000 RS-232 port requires a 9-pin male to 9-pin male null-modem cable. This cable is available as CSI Item # 14392.

A 12-Volt Field Power Cable (Item # 14291) or AC adapter (Item # 15966) must be installed to furnish 12 V to the “DC Pwr” connector on the RF400. The RF400 can operate with Active Interface in either the Auto Sense mode (default) or in the RS-232 mode with this configuration.

With the CR23X, the *D 12 “--” setting (to turn datalogger RS-232 port on) is not required.

Appendix G. Short-Haul Modems

Set SRM-5A at PC end to “DCE” mode.
Set SRM-5A at RF400 end to “DTE” mode.

The PC to SRM-5A cable is typically a 9-pin female to 25-pin male (CSI Item # 7026). The SRM-5A to RF400 cable is 25-pin male to 9-pin male available as CSI Item # 14413.

LoggerNet or PC208W Network Map:

COM1
CR10X1

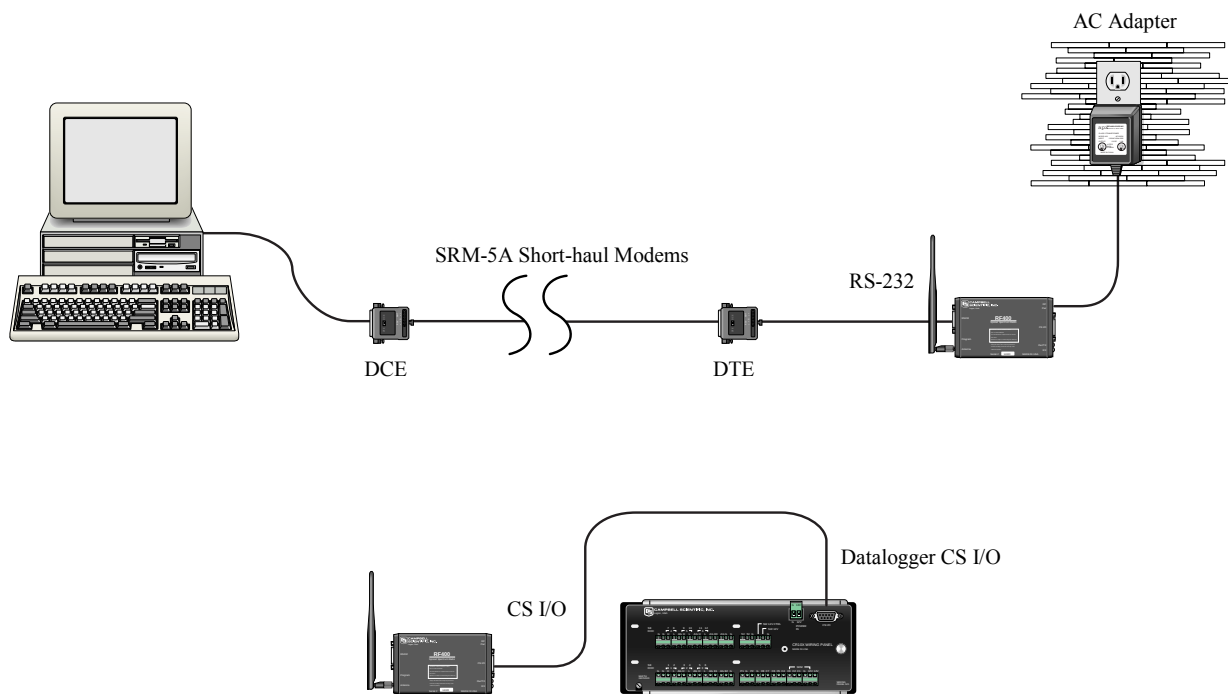


FIGURE G-1. Short-Haul Modem to RF400 Setup

Configure RF400s for point-to-point (see Software Setup Section 5.3). Default settings should work unless there is a neighboring network (see Section 5.3.1, 4.d).

12 V power for the base RF400 can be supplied by an AC adapter as shown or a Field Power Cable (see Power Supplies in Section 4.4). Current dataloggers will supply remote RF400 power via serial cable.

NOTE

With short-haul modems it is necessary to configure the base station RF400's "RS-232 Auto Power Down Enable" (in the Advanced Setup \ Interface Parameters menu) to mode "0" which will maintain the radio's RS-232 port always active. This results in an additional constant 2 mA current drain by the RF400. If you don't do this, the base RF400's RS-232 port will turn off 30 seconds after activity and the attached SRM-5A which gets its power from the port will not receive any messages from the PC.

Appendix H. Distance vs. Antenna Gain, Terrain, and Other Factors

RF Path Examples		
Distance Achieved (miles)	Antennas	Path Between Radios
2	14204 OMNI ½ Wave 0 dBd* Whip to 14204 OMNI ½ Wave 0 dBd Whip	Virtual line-of-sight on valley floor with wetland foliage.
10	14204 OMNI ½ Wave 0 dBd Whip to 14204 OMNI ½ Wave 0 dBd Whip	Line-of-sight across a valley (on foothills approximately 300 feet above the valley floor on each end).
35	14204 OMNI ½ Wave 0 dBd Whip to 14201 9 dBd YAGI	Line-of-sight across a valley (on foothills approximately 300 feet above the valley floor on each end).

* dBd = decibel level compared to a simple dipole antenna

LINE-OF-SIGHT

You should arrange for a line-of-sight signal path between RF400s. At 900 MHz or 2.4 GHz there is little signal bending, however, there is reflection from hills, water, and conductive objects. Sometimes reflections provide a helpful path around an obstacle. There can be some trees and bushes in the signal path (with reduction in signal strength), but a hill will block the signal effectively. Thick trees can limit range to as little as 800 feet. Where possible avoid buildings and other man-made structures in the signal path as they absorb or reflect some of the direct wave, possibly below the level needed for communications.

ANTENNA HEIGHT

In situations where the RF400 antennas are situated virtually line-of-sight, the elevation of antennas (by choice of site or by installing a tower or mast) can substantially increase signal strengths. The amount of increase depends on factors in the propagation path between the radios including terrain, foliage, and man-made structures. Elevating one or both of the antennas essentially raises the signal path allowing the direct wave to better avoid absorption or reflection which can sometimes be more helpful than adding higher gain antennas.

GAIN ANTENNAS

Increasing antenna gains improves signal strength and distance. For example, the substitution of a 9 dBd yagi antenna where a 0 dBd OMNI existed theoretically extends the attainable distance by a factor of 2.8. Adding 9 dBd yagi antennas on both ends in place of 0 dBd OMNIs theoretically extends the distance by a factor of 7.9. The higher the yagi's gain, the narrower the beam width and the more critical it is that it be aimed right on target.

How Far Can You Go?

Distance Estimates for Spread Spectrum Radios

Overview

There is a great deal of interest in estimating the distance you can expect to achieve with the RF400 radios. Also of interest are the effects of cable length, antenna gain, and terrain. Some of these items are easy to quantify (cable loss, for instance); others are difficult to quantify (such as the effect of ground reflections). They are all important, though, and affect how well the RF system performs.

Probably the best approach to take in making range estimates is to do a site survey that considers the topography, location of antennas and radios, and cable lengths, make some assumptions about the path losses, and see if there is still some net gain. If there is, or if it is close, the next course is to actually try it out.

Link Analysis

In an RF system, there are gains (transmitter power, antenna gains, and receiver sensitivity “gain”) and losses (cable loss and path loss). If the gains exceed the losses, you have a connection; any excess is the “link margin”.

Parenthetical values pertain to 2.4 GHz

EXAMPLE GAINS

Transmitter Power	20 (17)
Transmitter Antenna	6
Receiver Antenna	6
<u>Receiver Sensitivity “gain”</u>	<u>110 (104)</u>

EXAMPLE LOSSES

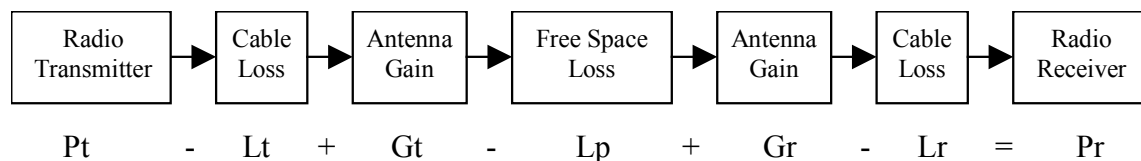
Transmitter Cable	3
Free Space	120
<u>Receiver Cable</u>	<u>3</u>

TOTAL GAINS = 142 (133) dB TOTAL LOSSES = 126 dB

Link Margin = (Total Gains) – (Total Losses) = 142 (133) – 126 = 16 (7) dB

A minimum of 6 dB of link margin is recommended.

Here is a block diagram of the various components of gain/loss:



Where:

- $P_t \Rightarrow$ transmitter output power, in dBm (20 dBm in the case of the RF400 or RF410)
- $L_t \Rightarrow$ cable loss between transmitter and antenna in dB (see Cable Loss section)
- $G_t \Rightarrow$ transmit antenna gain in dBi (dBi = dBd + 2.15)
- $L_p \Rightarrow$ path loss between isotropic antennas in dB (see Tables H-1, H-2)
- $G_r \Rightarrow$ receive antenna gain in dBi
- $L_r \Rightarrow$ cable loss between antenna and receiver in dB

$P_r \Rightarrow$ signal power at the radio receiver in dBm

The signal power at the receiver (P_r) must exceed the receiver sensitivity (−110 or −104 dBm) by a minimum of 6 dB for an effective link. The amount that P_r exceeds −110 dBm or −104 dBm (2.4 GHz) is the link margin.

All of these elements are known, or are easily determined, with the exception of L_p . Unfortunately, signal path loss can make the difference between a marginal link ½ mile apart, and a reliable link 10 miles apart!

Transmitter Power

Transmitter output power is often expressed in dBm, which is a decibel power rating relative to 1 milliwatt. The formula is: $\text{dBm} = 10 \log (P_t)$ with P_t expressed in milliwatts.

Transmitter Power (P_t) (milliWatts)	dBm
1	0
10	10
50 (RF415)	17
100 (RF400 or RF410)	20
1000	30
5000	37

Cable Loss

Cable loss is a function of cable type, length, and frequency and is usually specified as attenuation (dB) per 100' of cable. Using a low loss cable becomes very important as the cable run distances increase. Here are some typical cable types and their properties:

Cable Type	Outside Diameter	Loss (dB/100') @ 900 MHz	Loss (dB/100') @ 2.4 GHz
RG-58A/U	.195"	21.1	
COAX RPSMA-L	.195"	11.1	18.8
RG-8	.405"	6.9	
COAX NTN-L	.405"	4.5	8.1
LMR-400	.405"	3.9	6.7

*CSI stocked antenna cables are shaded.

CSI's "COAX RPSMA-L" uses LMR-195 antenna cable. Cable loss is proportional to length as the following table illustrates.

LMR-195 Cable Loss vs. Length @ 900 MHz	
LENGTH (ft.)	LOSS (dB)
100	11.1
50	5.6
25	2.8
10	1.1
6	0.7

Antenna Gain

Antenna gain is specified either in dBi (decibels of gain relative to an isotropic radiator) or in dBd (decibels of gain relative to a dipole). The relationship is:

$$\text{dBi} = \text{dBd} + 2.15$$

Some antennas that are FCC approved for use with the RF400 series are:

Mfg.	Antenna Type	Band	Model	CSI Item #	dBd Gain	dBi Gain	Size
Astron	Omni (1/2 wave)	900 MHz	AXH900 RP SMA R	14204	0	2.15	6.75"
Antenex	Collinear	900 MHz	FG9023	14221	3	5.15	24"
MaxRad	Yagi	900 MHz	BMOY8905	14201	9	11.15	21.4"
LINX	Omni (1/2 wave)	2.4 GHz	ANT-2.4-CW-RCT-RP	16005	0	2.15	4.5"
MaxRad	Enclosed Yagi	2.4 GHz	WISP24015PTNF	16755	13	15.1	17"

Receiver Sensitivity

Receiver sensitivity is usually specified in dBm for a specific bit error rate (BER). The transceiver module used in the RF400 (either 900 MHz radio) is specified at -110 dBm at $\sim 10^{-4}$ raw BER.

If the received signal strength is greater than the receiver sensitivity, a link can be established. Any excess signal strength above the receiver sensitivity is "link margin", and is a very good thing; a minimum of 6 dB of link margin should be sought.

Path Loss

We have combined in this section the normal "free space" path loss (only seen in mountaintop to mountaintop scenarios) with loss due to ground reflections, diffraction, leaf/forest absorption, etc. It is all loss!

A starting point is the "free space" path loss. Here are two equations for this:

$$\begin{aligned} L_p (\text{dB}) &= 32.4 + 20 \times \log(f) + 20 \times \log(d) \quad \text{dB} \quad (f \text{ in MHz, } d \text{ in km}) \\ L_p (\text{dB}) &= 36.6 + 20 \times \log(f) + 20 \times \log(d) \quad \text{dB} \quad (f \text{ in MHz, } d \text{ in miles}) \end{aligned}$$

Here is a table showing the free space path loss (in dB). Note the effect of frequency.

Frequency	Distance								
	1 mi.	2 mi.	4 mi.	8 mi.	10 mi.	16 mi.	22 mi.	26 mi.	30 mi.
400 MHz	89	95	101	107	109	113	115	117	118
915 MHz	96	102	108	114	116	120	123	124	125
2.4 GHz	104	110	116	122	124	128	131	133	134

Notice the relationship between path loss and distance: each time you double the distance, you lose 6 dB of signal under free space conditions. Or, put another way, if you add 6 dB of gain (for example with 6 dB of additional antenna gain, or 6 dB *less* cable loss), you can double the distance for free space conditions.

As mentioned before, free space conditions are the ideal, but seldom actually seen. The higher the antenna height relative to the terrain in the line of sight path, the closer to free space conditions. Antenna height is everything!

Here are some additional propagation effects that increase the path losses:

Diffraction

This is caused by objects close to the line of sight path. Real world examples of this would be hills, buildings, or trees. The object may not be in the direct line-of-sight, but if it is close enough, it will cause the RF to diffract around the object, giving additional path loss. “Close enough” is a function of frequency, path length, and position of the obstacle along the path.

An example at 900 MHz: a 10 mile path length with an obstacle halfway along the path will see diffraction “losses” from an obstacle within ~70 ft. of line-of sight. The amount of loss would be from 6 dB to 20 dB, depending on the obstacle surface. A sharp edge (like a rock cliff) would give the minimum loss (6 dB), while a rounded hill would give the maximum loss (20 dB).

Ground Reflections

These are caused by the RF signal being reflected from the ground (or water), and undergoing a phase shift so that it destructively interferes with the line of sight signal. The conditions that cause this the most are propagation over water, or over a low-lying fogbank. The reflected signal suffers little attenuation, gets out of phase, and interferes with the main signal. If antennas need to be sited near water, they should be positioned away from the water’s edge so that the ground vegetation attenuates the reflected RF.

The result of the reflection and interference (worst case) is that the path loss increases as the 4th power of the distance, instead of the 2nd power. This changes the distance term in the path loss equation to: $40 \times \log(d)$ dB. Then, with each doubling of distance, the path loss increases by 12 dB, instead of 6 dB.

Vegetation

Losses due to vegetation (trees, bushes, etc) cause the path loss to increase by the 3rd to 4th power of the distance, instead of the 2nd power. This is just like in the severe ground reflection case above.

Rain, Snow, and Fog

Below 10 GHz, these don’t have much effect on path loss (see Ground Reflections).

Real World Distance Estimates

From the above discussion of departures from the ideal “free space” path loss, it is clear that we should usually use something other than the 2nd power distance table.

Here is a table which gives calculated path loss (Lp) values at 900 MHz for the 2nd, 3rd, and 4th powers of distance; the equations (for 915 MHz) are:

$$L_p (2^{\text{nd}} \text{ power}) = 95.8 + 20 \times \log (d) \text{ dB} \quad (d \text{ in miles})$$

$$L_p (3^{\text{rd}} \text{ power}) = 95.8 + 30 \times \log (d) \text{ dB} \quad (d \text{ in miles})$$

$$L_p (4^{\text{th}} \text{ power}) = 95.8 + 40 \times \log (d) \text{ dB} \quad (d \text{ in miles})$$

Example calculated Lp values (in dB)

TABLE H-1. 900 MHz Distance vs. Path Loss (Lp in dB) per Three Path Types										
Path Type	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	14 mi.	18 mi.	22 mi.	26 mi.	30 mi.
2 nd power	102	108	111	114	116	119	121	123	124	125
3 rd power	105	114	119	123	126	130	133	136	138	140
4 th power	108	120	127	132	136	142	146	149	152	155

The following table helps select a Path Type in the above “Distance vs. Path Loss” table to best fit your situation.

TABLE H-2. Path Type vs. Path Characteristics Selector	
Path Type	Path Characteristics
2 nd power	Mountaintop to mountaintop or Tall antenna towers Line-of-sight
3 rd power	Dominantly line-of-sight Low antenna heights Some trees
4 th power	At water’s edge (very reflective) Across field of grain (reflective) Lots of Trees (absorptive)

Examples

Some examples will help illustrate the tradeoffs in a link analysis. These examples will all use the RF400 900 MHz radio, and will use –107 dBm as the required power level at the radio receiver. This is 3 dB higher than the quoted sensitivity of –110 dBm, which will give us a 3 dB margin.

Here’s the equation we will use, from the first page:

$$P_t - L_t + G_t - L_p + G_r - L_r = P_r$$

Example #1

Antenex FG9023 antennas on each end, 20’ of LMR195 cable on one end, 10’ of LMR195 on the other end, antennas at 10’ height, fairly open terrain with a few trees. How far can I go?

$$P_t = 20 \text{ dBm}$$

$$L_t = 20' \times (11.1 \text{ dB}/100 \text{ ft}) = 2.22 \text{ dB}$$

$$G_t = G_r = 3 \text{ dBd} = 5.15 \text{ dBi}$$

$$L_r = 10' \times (11.1 \text{ dB}/100 \text{ ft}) = 1.11 \text{ dB}$$

Use -107 dBm for P_r , solve for L_p : $L_p = 135$ dB

Use the 3rd to 4th power tables: **Range from ~9 (4th power) to ~22 (3rd power) miles**

Example #2

Base has MaxRad BMOY8905 Yagi, with 50' of LMR195 cable on a 30' tower, also a lightening protection device with a VSWR of 1:1.75; remote also has a MaxRad BMOY8905 Yagi with 5' of LMR195 cable on a 4' pole. Terrain is mostly flat, with sagebrush. How far can I go?

$P_t = 20$ dBm

$L_t = 50' \times (11.1 \text{ dB}/100 \text{ ft}) = 5.55$ dB

$G_t = 9$ dBd = 11.15 dBi

$L_r = 5' \times (11.1 \text{ dB}/100 \text{ ft}) = .55$ dB

$G_r = 9$ dBd = 11.15 dBi

Need to include the loss from the surge arrestor: VSWR of 1:1.75 = .34 dB loss

Use -107 dBm for P_r , solve for L_p : $L_p = 143$ dB

Use the 3rd to 4th power tables: **Range from ~14 (4th power) to 30+ (3rd power) miles**

Example #3

You need to run 125' of cable for the transmitter:

How much loss if I use LMR195 cable? $125' \times (11.1 \text{ dB}/100') = 13.9$ dB

How much loss if I use LMR400 cable? $125' \times (3.9 \text{ dB}/100') = 4.9$ dB

If I am using path loss from the 2nd power table, and operating fine at 8 miles with LMR195 cable, how much more range could I expect if I use LMR400 cable (assuming similar terrain)?

$13.9 \text{ dB} - 4.9 \text{ dB} \Rightarrow 9 \text{ dB}$ more link margin

Loss at 8 miles: 114 dB; could tolerate $114 + 9 \text{ dB} = 123 \text{ dB}$ loss $\Rightarrow \gg \gg 22$ miles (14 miles more)

Appendix I. Phone to RF400 Series

Where a phone to RF400 Base is desired, the following configurations will provide Point-to-Point or Point-to-Multipoint communications. To have a base datalogger in this configuration requires that another RF400 be added at the base.

1. HARDWARE REQUIREMENTS

- a. RF400s
- b. COM210
- c. PS512M (or CH512R and battery)
(have built-in null-modems and supply power for RF400 and COM210)
- d. AC charger (CSI Item # 9591) or solar panel
- e. Two SC12 cables (one included with RF400 and one with COM210)

2. POINT-TO-POINT COMMUNICATIONS

PC-Modem ----- COM210-PS512M-RF400----- RF400-DL
(null-modem)

LoggerNet SETUP

- a. Setup:
 - ComPort_1
 - PhoneBase
 - PhoneRemote
 - RF400
 - RF400Remote
 - CR10X
- b. ComPort_1 – default settings
- c. PhoneBase
 - 1) Maximum Baud Rate – 9600
 - 2) Modem Pick List – per PC's phone modem
 - 3) Extra Response Time – 0 s
- d. PhoneRemote – input base site's phone number
- e. RF400 – make Attention Character: “-“ ; leave the rest defaults
- f. RF400Remote – Radio Address: “0” ; leave the rest defaults
- g. CR10X – default settings, schedule collections as desired

PC208W SETUP

- a. Device Map
 - COM1
 - Modem1
 - CR10X1
- b. COM port - Default settings

- b. ComPort_1 – default settings
- c. PhoneBase
 - 1) Maximum Baud Rate – 9600
 - 2) Modem Pick List – per PC’s phone modem
 - 3) Extra Response Time – 0 s
- d. PhoneRemote – input base site’s phone number
- e. RF400 – make Attention Character: “-“ ; leave the rest defaults
- f. RF400Remote – make Radio Address: “1“ ; leave the rest defaults
- g. RF400Remote_2 – make Radio Address: “2“ ; leave the rest defaults
- h. Dataloggers – default settings, schedule collections as desired

PC208W SETUP

a. Network Map

COM1

Modem1

Generic1

CR10X_1

CR10X_2

b. COM port - default settings

c. Phone Modem

- 1) Baud Rate – 9600
- 2) Modem Pick List – per PC's phone modem
- 3) Extra Response Time – 2000 ms

d. Generic Modem

- 1) Dialed Using phone # at base site
- 2) ✓ Make DTR Active and ✓ Hardware Flow Control

e. Datalogger 1

- 1) Dialed Using Generic Modem Dial String:
D1000T"---"R"OK"9200T"ATDT0001^m"R"OK"1200T"ATCN
^m"R"OK"1200
- 2) Set up scheduled collections as desired.

f. Datalogger 2

- 1) Dialed Using Generic Modem Dial String:
D1000T"---"R"OK"9200T"ATDT0002^m"R"OK"1200T"ATCN
^m"R"OK"1200
- 2) Set up scheduled collections as desired.

“0001” in the first ATDT command is the hexadecimal representation of the combined Network Address / Radio Address chosen for this example (i.e., Network Address = 0, Radio address = 1). The RF400 Setup Menu calculates and displays this number for you in Standard Setup as “0001h”.

RF400 CONFIGURATION

a. Base RF400

- 1) Active Interface: “COM2xx to RF400”
- 2) **AT Command Character:** “-”
- 3) All other settings: defaults

b. Remote RF400s

- 1) Radio Addresses: 1, 2, etc. (unique for each remote RF400 and must agree with respective RF400Remote settings)
- 2) All other settings: default

Note 1: Using a non “+” Command Character for the base RF400 is necessary so the phone modem in the path passes the AT commands on to the base RF400 rather than responding to them.

Note 2: If there is a neighboring RF400 network, you should change the Hopping Sequence of base and remote RF400s to a new setting to avoid interference (see Section 5.3.1 for method to detect neighboring network).

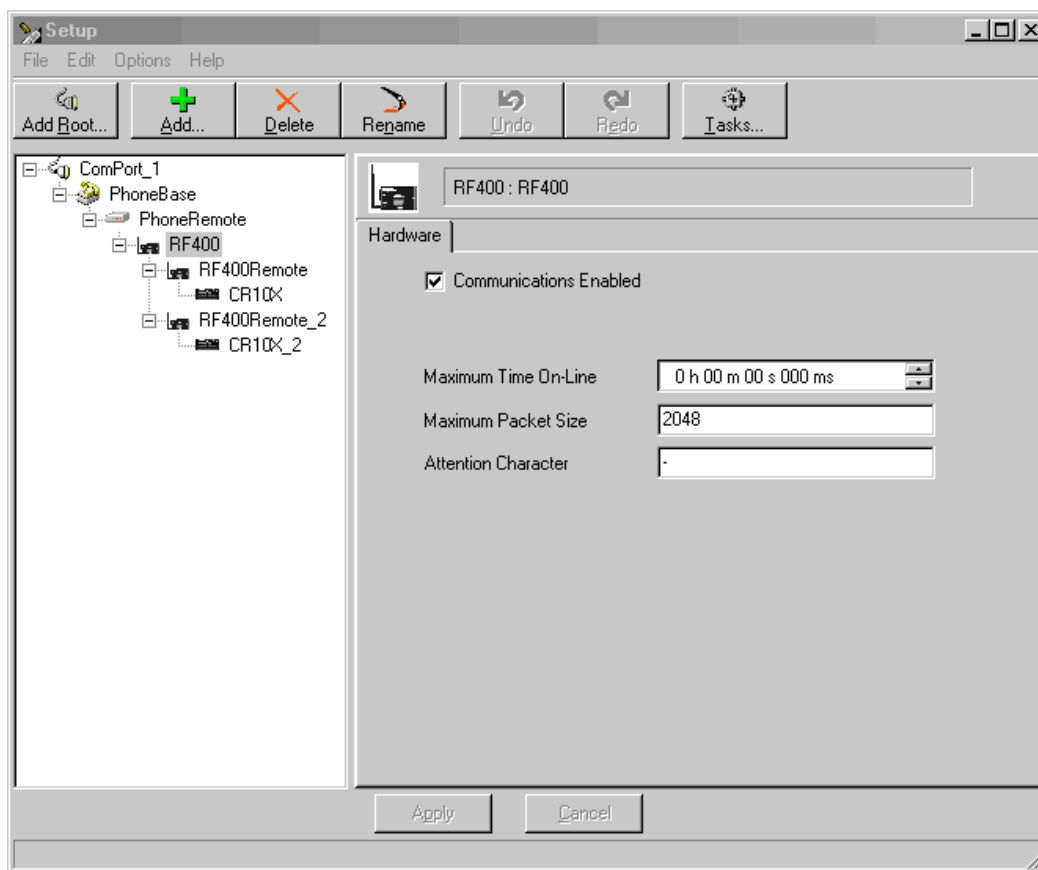


FIGURE I-1. LoggerNet Point-to-Multipoint Setup

4. HARDWARE

After configuring LoggerNet or PC208W and the RF400s you are ready to set up hardware. The PS512M null-modem connectors (it's not important which connector goes to which unit) connect via SC12 cables to the COM210 and the base RF400 CS I/O port. Connect the site phone line to COM210. Connect power to PS512M. Connect antenna to RF400. When you turn on the PS512M supply, the RF400 receives 12V power and you will see the LEDs light in their power-up sequence.

Remote RF400s normally connect to datalogger CS I/O ports via SC12 cables. Powering up the datalogger will start the RF400 operating. Install an antenna (or antenna cable and yagi or collinear) and you are ready to collect data.

Appendix J. Monitor CSAT3 via RF400 Series

Procedure for installing a pair of RF400 series spread spectrum radios for monitoring a CSAT3 system at a distance. This function has traditionally been implemented by running a short haul modem cable between CSAT3 and PC.

HARDWARE REQUIREMENTS

- Two RF400s (mounting bracket option available)
- Two RF400 antennas (and possibly cables, see Section 4.4 for options)
- Base Cable/Power Kit Item #14220 (contains 120V AC Adapter and 6 ft. PC to RF400 serial cable).
- Remote station 12V Field Power Cable Item # 14291 or (if 120VAC is available), AC adapter Item # 15966
- 9 pin male to 9 pin male null-modem serial cable (CSI Item # 14392)
- PC with HyperTerminal™ or Procomm™ for RF400 setup (if neighboring RF400s).
- Spare PC COM port (COMx)

RF400 SETUP

- (1) Plug AC adapter into 120VAC outlet; plug barrel connector into “base” RF400 and wait 10 seconds for RF400 to initialize.
- (2) Connect 6 ft. cable (from base kit) between PC COM port and base RF400 RS-232 port.
- (3) Run Hyperterminal™ or Procomm™ on PC and configure for
 - (a) Baud rate: 9600, 8-N-1
 - (b) Flow control: none
 - (c) Emulation: TTY
 - (d) ASCII
 - (e) COMx (direct connect)

Note: if using Hyperterminal™ it will probably be necessary to do a Call Disconnect and then a Call Connect for new settings to take effect.

- (4) Press “Program” button on RF400

The following text should be written to the terminal screen

Main Menu

SW Version XX.YYY

- (1) Standard Setup
- (2) Advanced Setup
- (3) Restore Defaults
- (4) Show All Current & Default Settings
- (5) Save All Parameters & Exit Setup
- (9) Exit Setup without Saving Parameters

Enter Choice:

- (5) Select “1” for “Standard Setup” and configure the following
 - (a) Active Interface – leave at default “Auto Sense”
 - (b) Network Address – can be default “0” if no neighboring RF400 networks are operating; otherwise choose a different network address (see RX LED Test below).
 - (c) Radio Address – can be default “0”
 - (d) Hopping Sequence – can be default “0” if no neighboring RF400 networks are operating; otherwise choose a different hopping sequence (1 – 6).

- RX LED Test -

To determine if there is a neighboring RF400 network in operation using the same hopping sequence as yours, stop communications on your network and observe RF400 green LEDs for activity. At this point, any green LED activity would indicate that there is a nearby network using the same hopping sequence.

The other network’s network and/or radio addresses might be different than yours, so having the same hopping sequence isn’t necessarily a serious problem but having an exclusive hopping sequence results in fewer retries.

- (e) Standby Mode – leave at default “2”
 - (f) Retry Level – if RF noise is a problem, try “Low” or a higher level to see if response improves.
- (6) Repeat steps 1 - 5 with “remote” RF400. Temporarily use 6 ft. cable and AC adapter during the remote RF400 setup. CSAT3 monitoring requires a Point-to-Point network so you should configure all remote RF400 settings the same as you did for the base RF400.

CSAT3 SETUP

- (1) Power CSAT3 off and then back on
- (2) Connect CSAT3’s RS-232 cable to the desired PC COM port
- (3) Run CSAT32 software
- (4) Select correct COM port if necessary under Settings\Communication
- (5) Enter Terminal mode (bottom tab)
- (6) Open Port (if not already open)
- (7) Press [Enter] a couple of times to get “>” prompt
- (8) Enter “br 0” and press [Enter] to send it to CSAT3 to configure RS-232 communications to 9600 baud (the RF400 always communicates at 9600 baud).
- (9) Enter “ri 1” and press [Enter] to send it to CSAT3 to turn on RS-232 drivers (if you want to save this setting in non-volatile RAM, refer to CSAT3 Instruction Manual, Appendix B).
- (10) Return to Data mode (bottom tab)

HARDWARE SETUP

- (1) Base station
 - (a) Plug AC adapter into 120 VAC outlet and barrel connector into “DC Pwr” jack on base RF400.
 - (b) Connect 6 ft. cable (from base kit) between PC COM port of choice and RF400 RS-232 port.

- (2) Remote station
 - (a) Connect 12 V power supply to RF400 (can be either 120V AC adapter or 12V Field Power Cable)
 - (b) Connect 9 pin male to 9 pin male null-modem cable from CSAT3 RS-232 connector to RF400's RS-232 connector.
 - (c) You are ready to start taking measurements

TROUBLESHOOTING

- (1) If your readings appear off-scale, try closing CSAT32 and running it again.
- (2) If not communicating with anemometer, make sure RS-232 driver is turned on (see CSAT3 SETUP).

Appendix K. RF400/RF410 Pass/Fail Tests

This appendix describes a method to functionally test RF400/RF410 system components including:

- PC COM port
- SC12 serial cable
- RF400/RF410
- RF400/RF410 Antenna

Hardware/Software Required

- ✓ PC with one available COM port
- ✓ Terminal Program (HyperTerminal™ or Procomm™)
- ✓ Two RF400/RF410s
- ✓ Two SC12 serial cables
- ✓ ¼ wave OMNI antenna (CSI Item # 14310)
- ✓ Two power supplies rated 12 Volts, 1 Amp
(recommend AC adapter Item # 15966 and any 12 V battery pack with Field Power Cable Item # 14291)

The following descriptions tell how to build an RF400/RF410 loop-back test system. Recommendations are given as to where to place the system to avoid rf-reflections (see TESTING ¼ Wave Antenna footnote ² in this appendix). The basic parts of the system are:

- 1) PC running a terminal program and a serial cable from PC COM port to base RF400/RF410
- 2) Base RF400/RF410
- 3) Remote RF400/RF410 with RS-232 port jumper wire between TX (pin 2) and RX (pin 3) for data loop-back.

Build the RF400/RF410 test system in the order shown:

- 1) TESTING SC12 CABLE and PC COM PORT
- 2) TESTING RF400/RF410s
- 3) TESTING ANTENNAS

Label components of the system “known-good” as they pass the test.

TESTING SC12 CABLE and PC COM PORT

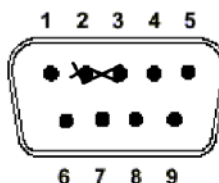
- (1) Run a terminal program such as HyperTerminal™ or Procomm™
 - (a) Baud rate: 9600
 - (b) Data, Parity, Stop Bits: 8-N-1
 - (c) Flow control: none

- (d) Emulation: TTY
- (e) ASCII
- (f) COM1 (or any available COM port)

NOTE

With some versions of HyperTerminal™ after changing a setting it is necessary to do a “Call Disconnect” (or “Disconnect”) followed by a “Call Connect” (or “Call”) for the new setting to register.

- (2) Connect an SC12 to the selected PC COM port either directly or via known-good RS-232 cable.
- (3) Temporarily short together pins 2 and 3 (RX and TX) of the SC12 cable’s male connector using a small (22 - 24 gage) copper wire, PC card jumper, or flat-bladed screwdriver. Take care to connect only pins 2 and 3.



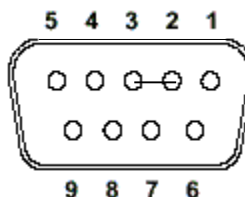
End view of male SC12 Connector

- (4) Press any alpha-numeric keys on PC keyboard.

NOTE

Make sure that Properties/Settings/ASCII Setup “Echo characters locally” or the equivalent Procomm™ setting is NOT enabled.

- (5) If the SC12 cable is good you will see characters “echo” to the screen as you press the keys.
- (6) Remove the short circuit from the SC12 connector. Key presses should now cease to echo back.
- (7) Test the SC12 cable’s female drop by gently inserting a u-shaped portion of paper-clip into pins 2 and 3 and repeating steps 4 to 6 inclusive.



End view of female SC12 Connector

CAUTION

Be sure to remove shorts between pins 2 and 3 when done.

TESTING RF400/RF410s

After verifying the functionality of the terminal program and the integrity of the serial cable and COM port, proceed as follows:

- (1) Connect 12V power to an RF400/RF410. This can be from an AC adapter (Item # 14220 or Field Power Cable (Item # 14291) with 12V battery pack attached (see step 12 below).
- (2) Connect first RF400/RF410's RS-232 port to the PC COM port
- (3) Run a terminal program such as HyperTerminal™ or Procomm™
 - (a) Baud rate: 9600
 - (b) Data, Parity, Stop Bits: 8-N-1
 - (c) Flow control: none
 - (d) Emulation: TTY
 - (e) ASCII
 - (f) Desired COM port

NOTE

Make sure that Properties/Settings/ASCII Setup "Echo characters locally" or the equivalent Procomm™ setting is NOT enabled.

- (4) Press "Program" button on RF400/RF410
- (5) Select "3" to restore defaults, then select "5" to save parameters and exit

NOTE

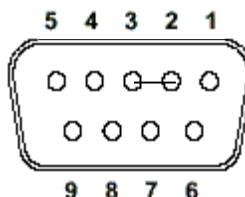
The presence of a neighboring RF400/RF410 network with default settings could interfere with your tests (see Section 5.3.1. (4.d) for detection method).

- (6) Repeat steps 1 to 5 inclusive with second RF400/RF410
- (7) Label the RF400/RF410 connected to the PC COM port as "Base"
- (8) Place the two RF400/RF410s side by side with antenna connectors 1 1/8 inches apart on a non-metallic surface (see Figure K-1).



FIGURE K-1. Loop-back Test without Antennas

- (9) Make sure that no antennas are attached to the RF400/RF410s
- (10) Label the other RF400/RF410, “Remote”
- (11) Insert jumper into the Remote RF400/RF410’s RS-232 connector pins 2 and 3 (using a U-shaped portion of a paper clip) allowing data received from base RF400/RF410 to be transmitted back to terminal screen by remote RF400/RF410.



RF400/RF410’s RS-232 Connector (female)

- (12) Connect 12V power to Remote RF400/RF410. This can be supplied by an AC adapter (Item # 14220) or Field Power Cable (Item # 14291) connected to a 12V battery (battery can be an 8 cell pack of alkaline A, C, or D cells, or a lead-acid battery).

NOTE

If your 12V power supply is a battery pack or rechargeable battery, make sure that the batteries are fresh or well-charged so they can supply the 75 mA peak current needed when the RF400/RF410 is transmitting in order to obtain valid test results.

CAUTION

For safety, people should maintain 20 cm (8 inches) distance from antenna while RF400/RF410 is transmitting.

- (13) Type 8 groups of 5 characters on the terminal (aaaaabbbbcccc etc.)
- (14) You should see 100% of the characters typed echo back to the screen

TESTING ANTENNAS

After setting up the terminal program and verifying the integrity of the COM port, serial cable, and RF400/RF410s, you are ready to test an RF400/RF410 antenna. Prepare to test an antenna by:

- Orienting RF400/RF410s so that the antenna connectors are on top
 - Fastening RF400/RF410s to cardboard boxes or other non-metallic structures maintaining antenna connectors 20 inches above the floor.
- (1) TESTING $\frac{1}{4}$ Wave Antenna
 - (a) Connect 12V power to base RF400/RF410 and remote RF400/RF410. We recommend AC adapter Item # 15966 or a Field Power Cable Item # 14291 connected to a 12V battery pack or 12V power supply.¹

- (b) Choose an open area free of large² metal objects within 10 feet of the RF400/RF410s (can be indoors or outdoors).
- (c) Attach a 1/4 wave omni antenna (Item # 14310) to base RF400/RF410
- (d) Set up remote RF400/RF410 with NO antenna
- (e) Separate RF400/RF410s by 5 feet
- (f) Type 8 groups of 5 characters on the terminal (aaaaabbbbcccc etc.)
- (g) You should receive 100% of the characters
- (h) With bad or missing 1/4 wave OMNI antenna you should get few to no characters echoed back.

¹ Be careful to not exceed maximum supply voltage of 18 VDC to RF400/RF410. Use “quiet” power supply without noise or hum (a 12V lead-acid battery is fine, if no trickle charger is attached during the tests).

² Examples of “large metal objects”: a steel filing cabinet; steel trim on cubicle dividers; or steel shelving. Especially avoid such metal objects facing the RF400/RF410s broadside. The idea is to avoid significant reflected signals because they can add to or subtract from the direct wave signal making test results vary a lot according to exact location. A fully absorbent rf environment with no reflections would be ideal.

(2) TESTING YAGI or COLLINEAR ANTENNA

- (a) Connect 12V power to base RF400/RF410 and remote RF400/RF410. We recommend AC adapter Item # 15966 or a Field Power Cable Item # 14291 connected to a 12V battery pack or 12V power supply (see footnote 1 above).
- (b) Choose an open area to conduct the tests (see footnote ² above).
- (c) Attach the yagi or collinear antenna being tested to base RF400/RF410
 - (i) A yagi can be mounted on a microphone stand or similar (metal, wood or PVC ok). Orient antenna elements vertically as shown in figure below and adjust height so the bottoms of the elements are 20 inches above floor. Aim yagi at remote RF400/RF410.



FIGURE K-2. Vertically Polarized 9 dBd 900 MHz Yagi

- (ii) A collinear antenna should be solidly mounted in a vertical position so that its omnidirectional “pancake” pattern is horizontal. A metal or wooden stand can be used.



FIGURE K-3. 3 dBd 900 MHz Collinear Omni Antenna

- (d) Set up remote RF400/RF410 with NO antenna and with antenna connector 20 inches above floor.
- (e) Arrange antenna distance apart according to following table.

TABLE K-1. 900 MHz Gain Antenna Test Distances			
Antenna	Gain Over ¼ Wave	Power Ratio vs. ¼ Wave	Distance Apart* (5 ft. $\times$ $\sqrt{\text{Power Ratio}}$)
9 dBd	11.2 dB	13.18	18 ft.
6 dBd	8.2 dB	6.61	13 ft.
3 dBd	5.2 dB	3.31	9 ft.
-2.2 dBd	0 dB	1.0	5 ft.

* This assumes a signal strength vs. distance relationship of $1/d^2$

- (f) Type 8 groups of 5 characters on the terminal (aaaaabbbbcccc etc.)
- (g) 100% of characters should appear on screen with good yagi/collinear antenna.
- (h) Removing yagi/collinear antenna, you should get no echoed characters.

Appendix L. RF400/RF410 Average Current Drain Calculations

For remote sites with tight power budgets due to solar or battery power supplies, the following will help determine average current consumption. The RF400/RF410's average current drain is based on:

- Standby mode of RF400/RF410
- Data collection interval
- Number of data points collected
- “Time of inactivity to sleep” selection

STANDBY MODES

TABLE L-1. Advanced Setup Menu			
STANDBY MODE	STANDBY AVG RECEIVE CURRENT (Is)	DEFAULT TIME OF INACTIVITY TO SLEEP (sec)	“LONG HEADER” LENGTH (L)
0 ¹	< 24 mA	----	0 ms
3 ²	< 4 mA	5	700 ms
4 ³	< 2 mA	5	1200 ms
5	< 1 mA	5	2200 ms
6	< 0.6 mA	5	4200 ms
7 ⁴	< 0.4 mA	5	8200 ms

¹ Standard Setup menu selection 1

² Standard Setup menu selection 2

³ Standard Setup menu selection 3

⁴ Standard Setup menu selection 4

CALCULATIONS

BASE

The average current drain of a *base* RF400/RF410 configured for scheduled collections has 5 contributors:

- 1) The STANDBY AVG RECEIVE CURRENT – Is
- 2) The average transmit current of LONG HEADER – Ih
- 3) The average transmit current of data request transmissions – Iq
- 4) The average receive current of data receptions – Ir
- 5) The average receive current of “time of inactivity to sleep” – Ii

The base RF400/RF410's total average current (It) can be calculated over an interval (T) as follows:

$$I_t = I_s + I_h + I_q + I_r + I_i$$

$$I_s = \{\text{table value}\}$$

$$I_h = \frac{L \text{ (ms)}}{T \text{ (ms)}} \times 73 \text{ mA} \quad \text{where L is the "long header" length}$$

$$I_q = \frac{20 \text{ (ms)}}{T \text{ (ms)}} \times 73 \text{ mA}$$

$$I_r = \frac{[45 \text{ (ms)} + 2 \text{ ms per data point}]}{T \text{ (ms)}} \times 24 \text{ mA} \quad (4 \text{ ms per high - res data point})$$

$$I_i = \frac{5000 \text{ ms}}{T \text{ (ms)}} \times 24 \text{ mA} \quad (\text{using default "time of inactivity to sleep"} = 50)$$

REMOTE

The average current drain of a *remote* RF400/RF410 being collected on schedule has 4 contributors:

- 1) The STANDBY AVG RECEIVE CURRENT – Is
- 2) The average transmit current from data transmission – Id
- 3) The average receive current of data request receptions – Ir
- 4) The average receive current from “time of inactivity to sleep” – Ii

The remote RF400/RF410's total average current (It) can be calculated over an interval (T) as follows:

$$I_t = I_s + I_d + I_r + I_i$$

$$I_s = \{\text{table mA value}\}$$

$$I_d = \frac{[45 \text{ (ms)} + 2 \text{ ms per data point}]}{T \text{ (ms)}} \times 73 \text{ mA} \quad (4 \text{ ms per high - res data point})$$

$$I_r = \frac{20 \text{ (ms)}}{T \text{ (ms)}} \times 24 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{T \text{ (ms)}} \times 24 \text{ mA} \quad (\text{using default "time of inactivity to sleep"} = 50)$$

EXAMPLE #1 (Remote RF400/RF410 in default standby mode)

There is a Point-to-Point system with base RF400/RF410 and remote RF400/RF410. The *remote* station senses weather conditions and sends low-resolution data to final storage. The base station collects 10 data points from the remote station once per minute. Both stations are configured for “<4 mA, ½ sec Cycle” (the default standby mode). The remote station operates on solar power and we are interested in knowing the average current drain contribution of the RF400/RF410. From the above section:

$$I_t = I_s + I_d + I_r + I_i$$

Calculating each term:

$$I_s = \text{table mA value} = 4 \text{ mA}$$

$$I_d = \frac{[45 \text{ (ms)} + 2 \text{ N (ms)}]}{T \text{ (ms)}} \times 73 \text{ mA} = \frac{65 \text{ ms}}{60,000 \text{ ms}} \times 73 \text{ mA} = 0.08 \text{ mA}$$

$$I_r = \frac{20 \text{ (ms)}}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 0.008 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 2 \text{ mA}$$

$$I_t \approx 6.1 \text{ mA}$$

The dominant average current drain contributors are the standby mode current and the “time of inactivity to sleep” currents. If large quantities of data per minute were being generated/collected, then I_d would become a significant contributor. In this example the “time of inactivity to sleep” could be reduced because only 10 data points are sent per collection. Try a value of 10 instead of 50 reducing the I_i contribution from 2 mA to 0.4 mA.

EXAMPLE #2 (Base RF400/RF410 in default standby mode)

The *base* RF400/RF410 in the above example does more receiving and less transmitting than the *remote* RF400/RF410 so you might expect less average current drain, however, the amount of data being transmitted per minute is small, and the long header required is significant. Here are the results:

$$I_t = I_s + I_h + I_q + I_r + I_i$$

Calculating each term:

$$I_s = \text{table mA value} = 4 \text{ mA}$$

$$I_h = \frac{L \text{ (ms)}}{T \text{ (ms)}} \times 73 \text{ mA} = \frac{700 \text{ ms}}{60,000 \text{ ms}} \times 73 \text{ mA} = 0.875 \text{ mA} \quad (\text{default "long header" length} = 700 \text{ ms})$$

$$I_q = \frac{20 \text{ (ms)}}{60,000 \text{ (ms)}} \times 73 \text{ mA} = 0.025 \text{ mA}$$

$$I_r = \frac{[45 \text{ (ms)} + 20 \text{ ms}]}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 0.026 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 2 \text{ mA} \quad (\text{using default "time of inactivity to sleep"} = 50)$$

$$I_t \approx 6.9 \text{ mA}$$

As in Example #1, the standby mode current, long header, and the “time of inactivity to sleep” currents dominate the average RF400/RF410 current drains, so the calculated values for remote and base RF400/RF410s are nearly equal. Larger data collections would make the I_r contribution more significant.

EXAMPLE #3 (Base RF400/RF410 in “<0.4 mA, 8 sec Delay” standby mode)

The RF400/RF410s in this example are configured for the lowest possible average standby mode current (Advanced Setup Menu selection 7). The same amount and frequency of data are collected as in Example 1.

$$I_t = I_s + I_h + I_q + I_r + I_i$$

Calculating each term:

$$I_s = \text{table mA value} = 0.4 \text{ mA}$$

$$I_h = \frac{L \text{ (ms)}}{T \text{ (ms)}} \times 73 \text{ mA} = \frac{8200 \text{ ms}}{60,000 \text{ ms}} \times 73 \text{ mA} = 10 \text{ mA} \quad (\text{"long header" length} = 8200 \text{ ms})$$

$$I_q = \frac{20 \text{ (ms)}}{60,000 \text{ (ms)}} \times 73 \text{ mA} = 0.025 \text{ mA}$$

$$I_r = \frac{[45 \text{ (ms)} + 20 \text{ ms}]}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 0.026 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 2 \text{ mA} \quad (\text{using default "time of inactivity to sleep"} = 50)$$

$$I_t \approx 12.4 \text{ mA}$$

EXAMPLE #4 (Remote RF400/RF410 in “<0.4 mA, 8 sec Delay” standby mode)

The RF400/RF410s in this example are configured for the lowest possible average standby mode current (Advanced Setup Menu selection 7). The same amount and frequency of data are collected as in Example 1.

$$I_t = I_s + I_d + I_r + I_i$$

Calculating each term:

$$I_s = \text{table mA value} = 0.4 \text{ mA}$$

$$I_d = \frac{[45 \text{ (ms)} + 2 \text{ N (ms)}]}{T \text{ (ms)}} \times 73 \text{ mA} = \frac{65 \text{ ms}}{60,000 \text{ ms}} \times 73 \text{ mA} = 0.08 \text{ mA}$$

$$I_r = \frac{20 \text{ (ms)}}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 0.008 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{60,000 \text{ (ms)}} \times 24 \text{ mA} = 2 \text{ mA}$$

$$I_t \approx 2.4 \text{ mA}$$

In this example the dominant average current drain contributor becomes the “time of inactivity to sleep” current.

EXAMPLE #5 (Base RF400/RF410 in default "<4 mA, 1 sec Delay" standby mode)

The RF400/RF410s in this example are configured for the default average standby mode current. The same amount of data (10 data points) are collected as in Example 1, however the *frequency of collection* is changed from once a minute to once an hour.

$$I_t = I_s + I_h + I_q + I_r + I_i$$

Calculating each term:

$$I_s = \text{table mA value} = 4 \text{ mA}$$

$$I_h = \frac{L \text{ (ms)}}{T \text{ (ms)}} \times 73 \text{ mA} = \frac{700 \text{ ms}}{3,600,000 \text{ ms}} \times 73 \text{ mA} = 0.014 \text{ mA} \quad (\text{"long header"} = 700 \text{ ms})$$

$$I_q = \frac{20 \text{ (ms)}}{3,600,000 \text{ (ms)}} \times 73 \text{ mA} = 0.0004 \text{ mA}$$

$$I_r = \frac{[45 \text{ (ms)} + 20 \text{ ms}]}{3,600,000 \text{ (ms)}} \times 24 \text{ mA} = 0.0004 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{3,600,000 \text{ (ms)}} \times 24 \text{ mA} = 0.033 \text{ mA} \quad (\text{using default "time of inactivity to sleep"} = 50)$$

$$I_t \approx 4.1 \text{ mA}$$

EXAMPLE #6 (Base RF400/RF410 in “<0.4 mA, 8 sec Delay” standby mode)

The RF400/RF410s in this example are configured for the lowest possible average standby mode current (Advanced Setup Menu selection 7). The same amount of data are collected as in Example 1, however the *frequency of collection* is changed from once a minute to once an hour.

$$I_t = I_s + I_h + I_q + I_r + I_i$$

Calculating each term:

$$I_s = \text{table mA value} = 0.4 \text{ mA}$$

$$I_h = \frac{L \text{ (ms)}}{T \text{ (ms)}} \times 73 \text{ mA} = \frac{8200 \text{ ms}}{3,600,000 \text{ ms}} \times 73 \text{ mA} = .17 \text{ mA} \quad (\text{"long header" length} = 8200 \text{ ms})$$

$$I_q = \frac{20 \text{ (ms)}}{3,600,000 \text{ (ms)}} \times 73 \text{ mA} = 0.0004 \text{ mA}$$

$$I_r = \frac{[45 \text{ (ms)} + 20 \text{ ms}]}{3,600,000 \text{ (ms)}} \times 24 \text{ mA} = 0.0004 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{3,600,000 \text{ (ms)}} \times 24 \text{ mA} = 0.033 \text{ mA} \quad (\text{using default "time of inactivity to sleep"} = 50)$$

$$I_t \approx 0.6 \text{ mA}$$

EXAMPLE #7 (Remote RF400/RF410 in “<0.4 mA, 4 sec Cycle” standby mode)

The RF400/RF410s in this example are configured for the lowest possible average standby mode current (Advanced Setup Menu selection 7). The same amount of data are collected as in Example 1, however the *frequency of collection* is extended to once an hour.

$$I_t = I_s + I_d + I_r + I_i$$

Calculating each term:

$$I_s = \text{table mA value} = 0.4 \text{ mA}$$

$$I_d = \frac{[45 \text{ (ms)} + 2 \text{ N (ms)}]}{T \text{ (ms)}} \times 73 \text{ mA} = \frac{65 \text{ ms}}{3,600,000 \text{ ms}} \times 73 \text{ mA} = 0.001 \text{ mA}$$

$$I_r = \frac{20 \text{ (ms)}}{3,600,000 \text{ (ms)}} \times 24 \text{ mA} = 0.0001 \text{ mA}$$

$$I_i = \frac{5000 \text{ ms}}{3,600,000 \text{ (ms)}} \times 24 \text{ mA} = 0.033 \text{ mA}$$

$$I_t \approx 0.43 \text{ mA}$$

SUMMARY

Choosing a lower current standby mode does not always result in an overall lower average current for the *base* RF400/RF410 because, by selecting a lower current standby mode, the base RF400/RF410 must generate a longer “long header” which involves more transmit time at 73 mA. However, the remote site will normally benefit from a lower standby mode current since it does not usually transmit a “long header.”

If the remote station is doing call-backs, then the *remote* RF400/RF410 must initiate the connection by sending a “long header” so the remote RF400/RF410’s average current drain may be higher than that of the base RF400/RF410. Data collection may be a mixture of scheduled calls and call-backs (possibly event driven).

As collection intervals become longer, the effects of “time of inactivity to sleep” and data amount lessen and the average current drain approaches the stated standby mode current.

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